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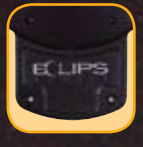

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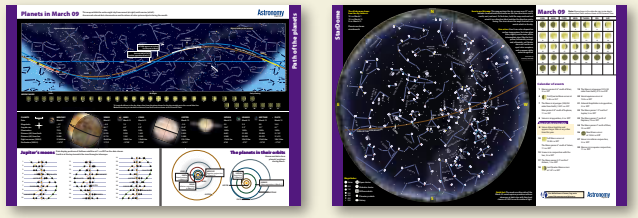

Path of the planets and StarDome.

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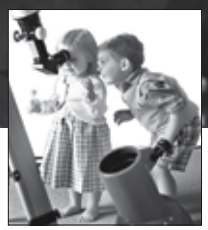

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The 6" Astro-Tech Ritchey-Chrétien was named a *Hot Product for 2009* when it was $1295. Imagine how hot it is now at only *$795!*

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Astro-Tech AT6RC 6" f/9 R-C

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R-C scopes used to come only in large apertures, with prices *starting* at $10,000. But no more! Advances in computerized mirror grinding and CNC machining let Astro-Tech produce *true Ritchey-Chrétien* photo/visual reflectors in more practical smaller apertures, at prices starting at an amazingly-affordable $795. Despite the low price, you still get the premium coma-free Ritchey-Chrétien performance you once had to pay a fortune to get.

The 6" **Astro-Tech AT6RC** is ideal for imaging with Deep Sky Imager-type cameras, webcams, and DSLRs. It has a metal tube, BK-7 mirrors with 1/12th wave or better optics, Crayford focuser, Vixen-style dovetail, and dust covers **$795**

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Check here next month for a price announcement on the 10" Astro-Tech R-C that will stun you *and* the competition!

Today, Celestrons do more and cost less.

8" CPC800, $1999

When we opened for business in 1979, a 5" Celestron C-5 SCT – with AC drive, tripod, and wedge – cost $903.

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For 11% less money, today's 5" Celestron has better optical coatings than the 1979 version, a better eyepiece, a drive conveniently powered by flashlight batteries, and a go-to computer that automatically finds 40,000 celestial objects for you.

Here's another example. The bare-bones C-11 SCT cost $3185 in 1979. Today, the fully-computerized and optically better 11" CPC1100 costs only $2799.

A wider variety of more advanced and more capable telescopes, for less money. That's the Celestron way of life.

Here are the prices on some of the latest go-to Celestron Schmidt-Cassegrain telescopes . . .

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NexStar 6SE, 6" go-to single-fork altazimuth ... **999**
NexStar 8SE, 8" go-to single-fork altazimuth . **1399**
CPC 800, 8" go-to dual-fork altazimuth **1999**
CPC 925, 9¼" go-to dual-fork altazimuth **2499**
CPC 1100, 11" go-to dual-fork altazimuth **$2799**
CGEM 800, 8" go-to German equatorial **2099**
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CGEM 1100, 11" go-to German equatorial **2999**
CGE 1400, 14" go-to German equatorial **6134**

The return of the TMB planetary eyepiece.

TMB Planetary $64.95

After being sold out for months, the highly-acclaimed high power/long eye relief **TMB Optical®** planetary eyepieces are again in stock for serious lunar/planetary observing.

These are the only TMB Optical® eyepieces authorized by the estate of the late Thomas M. Back. They have been optimized to give you the highest contrast and sharpest possible images. Each 60° field TMB splits close binary pairs with ease and reveals subtle lunar and planetary detail you've only dreamed of seeing.

The 1.25" TMB comes in 2.5, 3.2, 4, 5, 6, 7, 8, and 9mm focal lengths ideal for today's fast focal ratio scopes.

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Better do in dew before dew do in you.

4 output/2 channel AstroZap controller **$105**

Astrozap dew shields slow the formation of dew that can shorten your viewing time and ruin your photos. Prices start at only $24.95, making the Astrozap dew shields our best-selling dew protection.

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The Celestron Sky Scout with GPS, *now only $199!*

The **Celestron SkyScout** *GPS-based* non-magnifying hand-held personal planetarium locates and identifies more than 50,000 celestial objects for you, including every one visible to your unaided eye. Earbuds or an optional speaker tell you their stories, or you can read them on the 5-line text and graphics display. The SkyScout was named "the perfect instrument to explore the sky" by the International Year of Astronomy 2009.

Sky align the Meade ETX-LS with your eyes closed.

Meade 6" ETX-LS $1299

The 6" **Meade ETX-LS** has some jaw-dropping new and unique features.

For instance, you never have to look through the eyepiece or red dot finder to align your ETX-LS on the sky. Its innovative LightSwitch™ Technology uses a GPS receiver, Level North Technology, and a built-in CCD camera that does the looking for you. It provides the only no-hands/eyes-closed alignment available in *any* consumer telescope.

And you don't need to take a computer outside to take photos through the ETX-LS. Its sensitive built-in wide-angle camera stores images on an SD card to view inside on your computer later or you can see them immediately using the scope's video output and an optional monitor.

Astronomer-Inside™ software guides you to the best objects in the night sky while a built-in speaker delivers a celestial encyclopedia of audio and video content to take you on an interactive guided tour of hundreds of night sky objects.

And Meade's 6" f/10 Advanced Coma-Free (ACF) catadioptric optics deliver the same sharp coma-free view as a professional Ritchey-Chrétien telescope, but without the R-C's high price tag.

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With Astro-Tech eyepieces, you see more, but spend less!

At $79.95 each, the new 60° field 5, 8, 12, 15, 18, and 25mm **Astro-Tech Paradigm Dual ED** 1.25" 6 element/4 group eyepieces have *two* ED elements for sharp, flat field images that will have you wondering why other eyepiece brands cost so much more.

And here are more great values . . .

Astro-Tech Titan 1.25" and 2" eyepieces have a wide 70° field, twist-up eyecups, high contrast, and low prices. Compare them to any other wide field eyepieces. At their low, low prices, these Astro-Tech Titans have no competition.

Titan 2" 38mm $99.95

Titan – 1.25", 70° field, 10 or 15mm **$59.95**
Titan – 1.25", 70° field, 20mm **69.95**
Titan – 2", 70° field, 26mm **79.95**
Titan – 2", 70° field, 32mm **89.95**
Titan – 2", 70° field, 38mm **99.95**

Want still more proof you *can* get more and pay less? Compare the **Astro-Tech Titan Type 2** 68° field 6-element 2" 30mm, 35mm, and 40mm *ED* eyepieces to similar eyepieces costing several times the $199 Astro-Tech price. Optically, you'll be hard-pressed to see any difference.

Titan Type 2 $199 2" 40mm

The Astro-Tech Voyager – "a really sweet grab-and-go."

A magazine review said that the $299 **Astro-Tech Voyager** altazimuth mount was "unusually stable for its size and weight" and was packed with "lots of first-class engineering" that made it "a really sweet grab-and-go setup that's ideal for viewing day or night."

The Voyager has a 20 pound payload capacity, automatic clutch worm gear manual slow motion controls, adjustable height aluminum tripod, a Vixen-style dovetail, and a very affordable $299 price. The Voyager is clearly today's best value in serious altazimuth mounts.

$299
Astro-Tech Voyager with optional Astro-Tech 4" AT102ED

This $69.95 2007 Hot Product diagonal is still hot!

$69.95

The **Astro-Tech 1.25" star diagonal**, like all Astro-Tech diagonals, has durable 46-layer 99% reflectivity *dielectric* coatings on its premium 1/10th wave BK7 optical glass substrate. In addition to its exceptionally high reflectivity, the very smooth ion-deposited dielectric surface improves contrast during lunar and planetary observing.

The 2" Astro-Tech BK7 dielectrics start at $119.95, while their 2" dielectric diagonals with genuine *quartz* substrates start at $189.95.

From $85 to $750, TeleVue eyepieces are worth it.

13mm Ethos 1.25"/2" $620

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We've been carrying TeleVue eyepieces and refractors for well over a quarter of a century, ever since the first TeleVue Plössls raised the bar forever on eyepiece performance in 1980. Still being made, the eight TeleVue Plössls prove that great design and premium optical performance never go out of style.

And few eyepieces have been as well received as the original 100° field 8mm and 13mm Ethos. They proved that eyepieces that cost more than many complete telescopes could indeed be worth the money.

Now that original Ethos duo is joined by two new 100° field Ethos eyepieces: a 6mm and a 17mm. They are sure to garner the same kind of rave reviews for their performance that the original 8mm and 13mm Ethos continue to receive even today.

Here are the sizes, prices, and fields of view of a few of the 43 superb TeleVue eyepieces we keep in stock.

Plössl – 1.25"; 50°; 8, 11, or 15mm ... **$85.00**
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35mm Panoptic – 2", 68° **380.00**
41mm Panoptic – 2", 68° **510.00**
Nagler Type 6 – 1.25"; 82°; 2.5, 3.5, 5, 7, or 8mm **290.00**
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The value of dark-sky observing

by David J. Eicher

Recently, I traveled to remote New Mexico to do several nights of observing for upcoming stories in the magazine. Later, someone asked me, "Why would you go so far to observe the night sky?" The answer reminds us all, as astronomy enthusiasts, of the value of a dark sky for viewing the heavens.

As activities go, astronomy offers us all the great advantage of having the same laboratory the professionals use — the night sky is visible virtually everywhere. But the view of the sky is hardly equal everywhere.

Unfortunately for amateur astronomers, a glance at a satellite image of the world at night shows the dramatic extent of light pollution. In the United States, city lights spilling upward into the night sky have swallowed up the eastern half of the country. Many other areas of the world are in the same state.

Sky darkness isn't the only issue, either. In Wisconsin, for example, even clear, dark nights are characterized by lots of particulates in the atmosphere and often by moisture in the air, too. Those attributes diminish the transparency of the sky, making observing relatively poor.

That's where the desert southwest comes in. Not only are skies truly dark there — in some areas as much as 10 times darker than out east — but the transparency of the sky is fantastic, too. Extremely low humidity, relatively high altitude (where I was), and freedom from airborne particulates make observing many factors better than in the Midwest.

In Animas, New Mexico, at the Rancho Hidalgo site of the Arizona Sky Village, we not only had some of the best skies I've seen, but we also used a 30-inch telescope, making virtually anything you wanted to observe visible. That's the kind of observing amateur astronomers want to do, want to read about, want to dream about. We will bring you the results of observations made at this observing site in future issues of the magazine.

Tony and Daphne Hallas

Dark skies over the Florida Keys make for good observing conditions.

Most of us live in or near cities out of necessity. But don't pass up the opportunity to observe from a truly dark sky. It's what this hobby is all about: enjoying the beauty of the sky and the stars, clusters, nebulae, and galaxies in it. It's also about simply soaking in the visual beauty of the sky seen with the eye alone, just as countless generations of humans did before civilization lit up the sky with wasted artificial light.

Yours truly,

David J. Eicher
Editor

Astronomy

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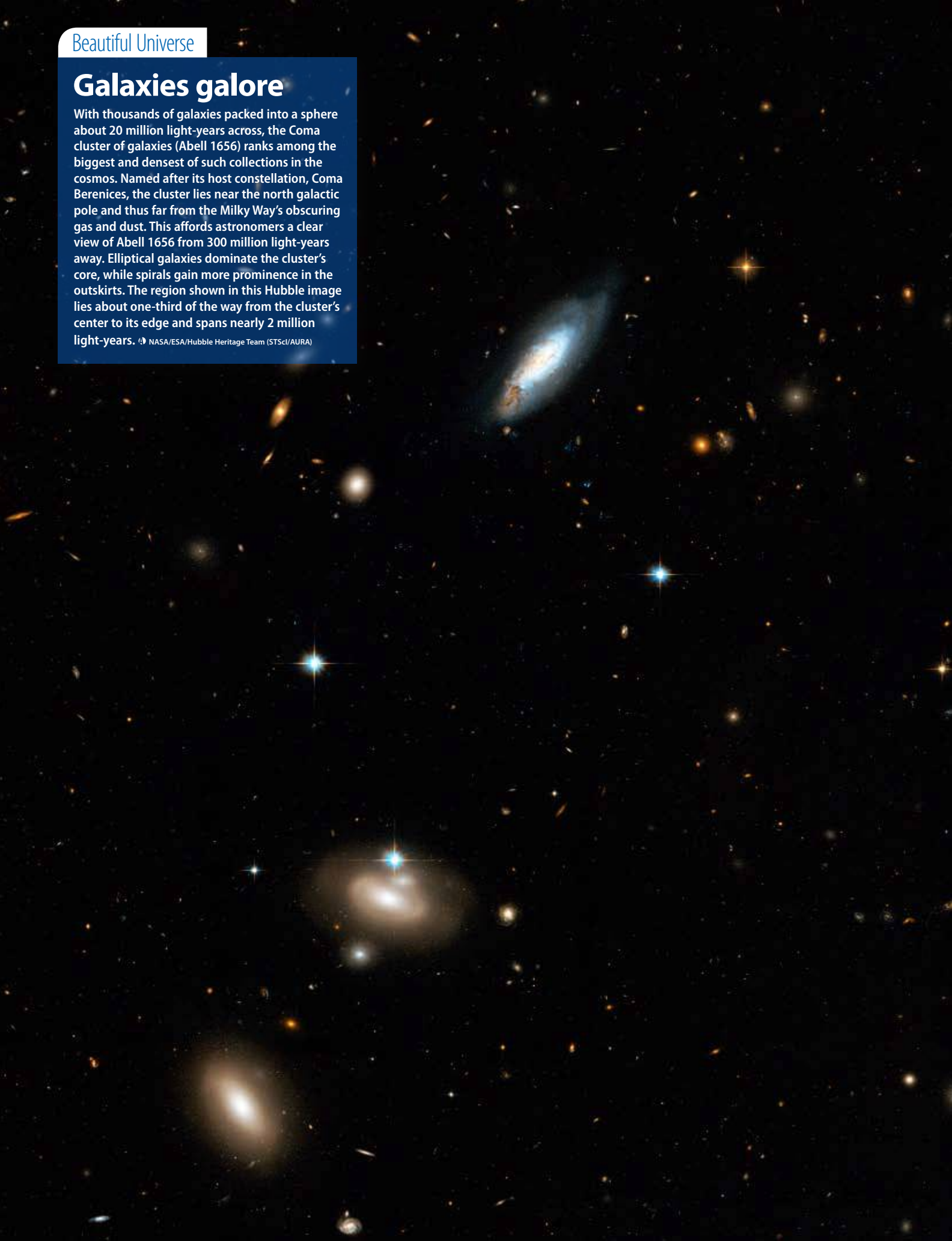
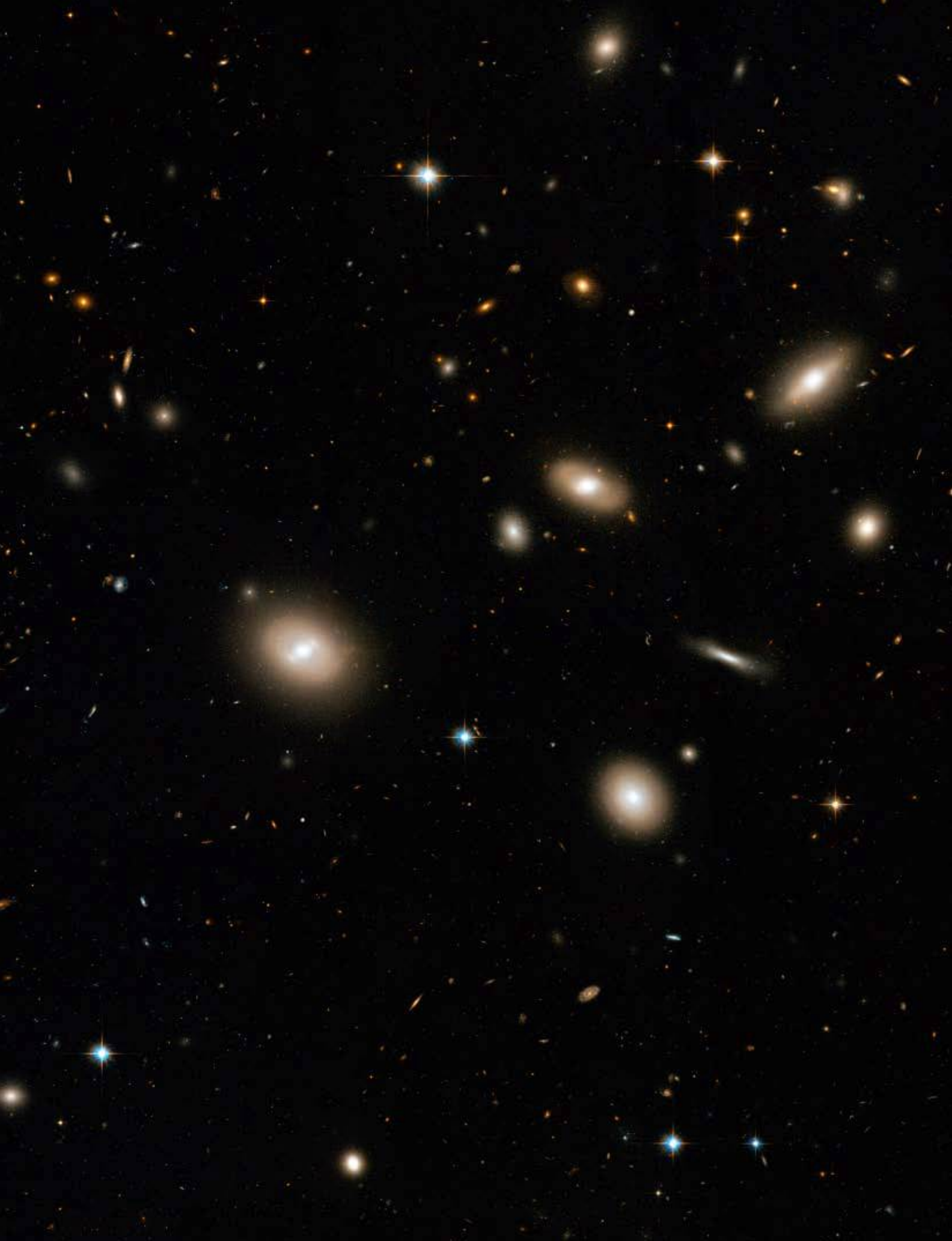
Galaxies galore

With thousands of galaxies packed into a sphere about 20 million light-years across, the Coma cluster of galaxies (Abell 1656) ranks among the biggest and densest of such collections in the cosmos. Named after its host constellation, Coma Berenices, the cluster lies near the north galactic pole and thus far from the Milky Way's obscuring gas and dust. This affords astronomers a clear view of Abell 1656 from 300 million light-years away. Elliptical galaxies dominate the cluster's core, while spirals gain more prominence in the outskirts. The region shown in this Hubble image lies about one-third of the way from the cluster's center to its edge and spans nearly 2 million light-years. NASA/ESA/Hubble Heritage Team (STScI/AURA)





Searching for the aurora australis

I marveled at the brilliant photographs of the aurora borealis by Hinrich Bäsemann in "Where the northern lights dance" (November 2008). But as a resident of Montevideo, Uruguay, currently working in New York, I am bewildered as to why, in all my years living in the southern regions of South America (including visits to the glaciers of Patagonia and other areas near the southern tip of the continent), I have never heard mention of the aurora australis, or southern lights, either from friends or in the media. Why is this? **— Cristina Reyes de Schleifer,** Montevideo, Uruguay

The aurora in the Southern Hemisphere is just as impressive as it is in the Northern Hemisphere. In fact, it is usually a mirror image. The aurora australis is less known than its northern cousin mostly due to the landmass distribution on Earth. First, the offset of the magnetic pole to the geographic pole is larger in the south, placing the magnetic pole away from South America, toward Australia and New Zealand.

The aurora therefore occurs mostly over Antarctica, as well as the Pacific and Indian oceans south of Australia.

The northern lights are more common in the media than their southern counterpart due to landmass distribution on Earth. Dan Bryden

In the Northern Hemisphere, however, Europe, and Asia reach far enough north to be under the auroral zone, so many more people in the north have a chance to see aurora than in the south. For example, during large magnetic storms, the aurora can be seen from the northern United States, while the aurora in the south is visible only on the horizon from Tasmania and southern New Zealand. Only once-a-century magnetic storms will push the aurora australis far enough north to be seen from the southern tip of Argentina's Tierra del Fuego. **— Dirk Lummerzheim,** Geophysical Institute, University of Alaska, Fairbanks

Man vs. machine

Astronomy was born at an interesting crossroads when the torch was passed from Moon walkers to robotic probes, so the magazine has existed entirely in an era dominated by armchair astronomers. With NASA trying to divide its budget between returning to the Moon and continuing its success with unmanned missions, we are again in a time of change.

Some scientists will argue that we can (and do) capably redefine our place in the cosmos while safely remaining within our own atmosphere. Inevitably, though, humans must — and will — step on Mars, probably within the next 35 years unless war, politics, and an uncertain economy confine us indefinitely to low Earth orbit. **— Frank Leblanc,** Daytona Beach, Florida

More naked-eye articles

In my area, the light pollution is horrible, which makes constellations hard to find. But with Stephen James O'Meara's "Naked-eye denizens of the galactic deep" (September 2008), I found two globular star clusters easily. Using Jupiter as a landmark for M22, I located M13 as well. It was a great report, and I look forward to more naked-eye articles. **— Daniel R. Bashore,** Franklin, Ohio

To learn about more naked-eye targets you can observe in the night sky, check out Senior Editor Michael E. Bakich's weekly podcast at www.Astronomy.com/podcast. ***— Astronomy* Editors**

Explaining Venus' climate

In "Taking Venus by storm" (October 2008), Robert Zimmerman explained what data from Venus Express have unveiled about the planet's climate. But with a venusian day lasting 117 Earth days and a year lasting 224.7 Earth days, wouldn't this near-tidal lock be a major factor in Venus' climate? I would think the 2° tilt and near-circular orbit (.007 eccentricity, the least elliptical of all the planets) play a part as well. **— Fred Whitaker,** Littleton, Colorado

The overriding factor in Venus' climate is its thick carbon dioxide atmosphere, which is most likely the result of Venus lying 30 percent closer to the Sun than Earth does. Even if Venus' axis were tilted significantly more and the planet had a more eccentric orbit, the thick atmosphere and hot climate would still exist. **— Richard Talcott,** Senior Editor

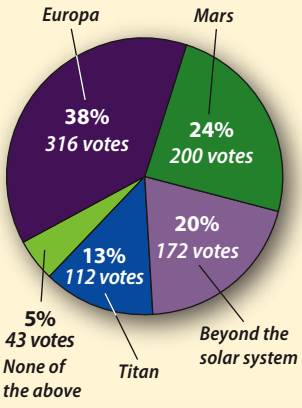
Problems with plutoids

I read your short note about a newly named "plutoid" ("IAU names a new plutoid," November 2008). It reminded me of my idea years ago (back when I was a contributor to *Astronomy*) that these trans-neptunian objects should be called "kuipers," not plutoids. Using the word plutoid is like calling asteroids "ceroids" after the first one discovered. It seems fitting to call them kuipers, after Gerard Kuiper, the astronomer who posited the category in 1951. **— John Mood,** San Diego

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

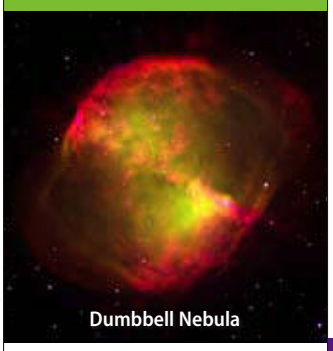
Online poll results

If we were to find microbial life on another world, where do you think it would be?



Total Votes: 843

Join the fun! You'll find the weekly question on the lower right side of Astronomy.com.



Dumbbell Nebula

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MESSENGER image of Mercury

"Is there something we don't know about gravity?" p. 22
Discover what isn't causing these gravity anamolies.

"Surprises from MESSENGER's historic Mercury flyby" p. 28
View a collection of images from MESSENGER flybys.

"Cassini flies through Enceladus' geysers" p. 32
Find more results from Cassini's October 2008 flybys.

"How the Spitzer Space Telescope unveils the unseen cosmos" p. 44
Learn more about Spitzer's past discoveries.

"Discover galaxy groups and clusters" p. 52
Find an observing guide for 10 more springtime galaxy groups and clusters.

Tune us in

Each week, *Astronomy* Senior Editor Michael E. Bakich, a master at explaining how to observe, posts a podcast about three objects or events you can see in the sky. Past observable objects have included:

- **Square of Pegasus**
- **Open cluster M103**
- **Spiral galaxy IC 342**
- **Dumbbell Nebula**
- **and many more!**

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***ASTRONOMY*'S HOW TO: OBSERVE GALAXIES**
Astronomy Editor and famed deep-sky observer David J. Eicher gives advice on teasing the most detail out of distant star cities.

This month's top blogs

Editors share their thoughts on current events in the staff blog. Join in the conversation!

Astronaut Buzz Aldrin on the Moon

1 ONE SMALL STEP FOR … OOOPS!
Many video producers continue to misrepresent Neil Armstrong's comments the day he stepped onto the Moon along with Buzz Aldrin. **BY DANIEL PENDICK, ASSOCIATE EDITOR**

2 TEACHING FUTURE SCIENTISTS
NASA announced a great new opportunity for teachers to use the space program's discoveries as educational tools in their classrooms. **BY KARRI FERRON, COPY EDITOR**

3 THE POWER OF HUBBLE
I'm a sucker for pretty astronomical images, and Hubble does not disappoint. **BY LIZ KRUESI, ASSOCIATE EDITOR**

Left, clockwise: Dumbbell Nebula: George Jacoby/WIYN/NSF; Mercury: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington; Buzz Aldrin: NASA

Strange Universe

by Bob Berman

Alien winds

The wind is a powerful force — even on other planets.

Recall a soft breeze on a warm night. Or a howling blizzard. Or dead calm in a summer field, with no sound except for a buzzing insect. Our experiences are shaped by the wind.

Blowing sands animate even the most lifeless desert. By contrast, worlds where no breeze has ever stirred, where dust lies flat for billions of years, have a dead and alien ambiance — as the Apollo astronauts saw firsthand. (Nor is there anything exciting under the Moon's powdery surface. We'll return only because, like Burger King, it's convenient.)

The topic of air motion often arises in March, the windiest month in many places. The culprit is air pressure differences created by the fierce battle between the Sun's maximum tropical intensity and Earth's still-frosty higher latitudes.

The opposite of March is Mercury. It's the only planet with no wind. Nothing ever changes there; it's like women's fashion in Uzbekistan.

Earth comes in second, with the gentlest breezes in the solar system. Everywhere else, the wind howls. The constant ear-splitting chaos on Jupiter and the F5 tornado-level westerlies on Saturn would be off the scale to human experience.

Venus, so spectacular right now, has just surrendered some of its windy secrets. With a pressure 90 times greater than that of Earth, its surface air is syrupy. It would feel as dense as water. The slightest breeze would knock you over. The Venus Express spacecraft's new study tells us pure carbon dioxide blows at 100 to 200 mph (160 to 320 km/h) a few dozen miles above the ground. But the south pole has a circular vortex, a permanent hurricane with absolute calm in the middle. If this high-altitude air behaves the same all the way down, the poles alone might offer an escape from Venus' brutal maelstroms.

Odd. The nearest planet barely spins at all, yet it has ferocious winds. Anyway, it hardly matters. Its broken thermostat is stuck on 850° Fahrenheit (455° Celsius). Venusian gusts are hotter than a furnace, blowing beneath stinking sulfuric-acid clouds on a world some master of irony has named "the Goddess of Love." We'll never go there.

Finally, to the only planet that might allow long visits (or maybe not, we'll see): Mars. Ongoing research reveals fatally thin air, with ground-level pressure matching ours at 19 miles (30 kilometers). Yet the Red Planet makes a little air go a long way. Snow falls from its clouds and gets blown by winds that can howl at 100 mph (160 km/h) at the surface. But its super-thinness limits its "push" to the gentle force of an earthly breeze. A martian flag would barely flutter.

Odd. The nearest planet barely spins at all, yet it has ferocious winds.

But that's enough to create a dynamic world. Dust devils swirl like anemic twisters over the ruddy sands. A future astronaut, perhaps on a mild day when the temperature hits the 30s, might boldly remove her helmet for a few safe seconds. With breath held and lids shut against eyeball-freezing (one of the quick abuses that ultra-low pressure inflicts), she might listen to the melody of the martian breeze. On no other world could a person experience the wind — and live. Science fiction often depicts unprotected villains exploding when they're expelled from their spaceship. But the famous scene in the movie *2001: A Space Odyssey* is closer to the truth, where a helmetless astronaut safely survives the vacuum for 10 seconds and then recompresses the airlock after the weird computer HAL locks him out. Vacuum experiments with chimps showed that the animals suffered no physical harm for 3 minutes, and a human who accidentally depressurized remained conscious and unhurt for 12 seconds before blacking out. Not that such impulsive behavior is listed in any NASA guidebook under "Things to try when you're bored."

Sometimes, during Mars' southern summers when the planet ventures closest to the Sun, the 20 percent boost in solar intensity makes the wind pick up. From a mere local phenom, it crescendos into a frenzied tempest the size of Europe. These events often start in the dusty Hellas Basin. Countless fine solids the size of cigarette smoke particles get pulled aloft, and a glow starts to spread: Martian dust storms reflect twice as much light as the rest of the planet.

Ten times in the past century, such a storm grew into a global tumult. All martian features vanished through our telescopes. The planet doubled its brightness in the night sky, and its color changed to yellow. Backyard skygazers needed no equipment to know the planet was engulfed. Where else beyond Earth can a naked-eye observer perceive the wind?

As in the Sahara, that world and any future astronauts in their protective habitats would then be hidden from the rest of the universe, the Sun obliterated.

Future Mars-o-nauts will ultimately see what the rest of us have always known. On Earth and in the heavens, when it comes to mood and sensations, the wind has no equal.

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About Your Professor

Dr. Mark Whittle is Professor of Astronomy at the University of Virginia, where he has taught for over 20 years. He earned his M.A. in Physics at Oxford University and his Ph.D. in Astronomy at the University of Cambridge. Professor Whittle is the author of more than 80 research articles.

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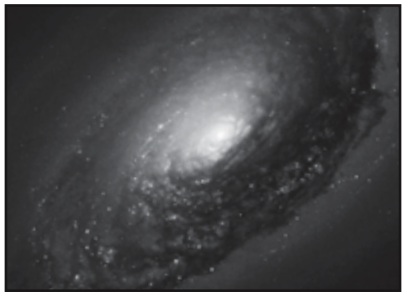

NASA and The Hubble Heritage Team (AURA/STScI).

Messier 64, nicknamed the "Black Eye" galaxy

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Secret Sky
by Stephen James O'Meara

Serpents of the air

Seek out the solar-eclipse phenomenon shadow bands any day of the year.

Few sky events can compare with experiencing a total solar eclipse. Unfortunately, many amateur astronomers have to enjoy these events vicariously because seeing one, more often than not, requires long-distance travel, time away from work, and deep pockets. But there is one fantastic solar eclipse wonder that you can search for every day with your unaided eyes. I'm talking about "shadow bands" — the most mysterious and animated of all eclipse phenomena.

At a solar eclipse, shadow bands occur just before and after totality or annularity. They manifest in a variety of shapes and forms, the most dramatic of which are the series of alternating dark and light lines, several feet in length, that slither across the ground, walls, and other structures like phantom snakes. But you do not need the Moon to cover the Sun to create shadow bands. Sharp, distant horizons at sunrise and sunset are just as effective in producing this natural atmospheric curiosity.

In essence, shadow bands are a scintillation effect (like the twinkling of stars), only in this case the illuminating source is not a starlike point but a long and slender solar crescent. Each point of light in that crescent travels through our turbulent atmosphere along a different path to the ground, where we see them interfering with one another — both constructively (enhancing light) and destructively (erasing light). The cumulative visual effect is a ripple pattern of light and dark waves (shadow bands) that move in concert with the air's ever-shifting currents.

Swiss observer Charles Dufour brought attention to the non-eclipse-related shadow bands as early as 1852. Reporting in the April 1906 issue of *The Observatory*, Dufour said that at the moment of sunrise, and for just 1 or 2 seconds, he saw "something resembling waves, alternately dark and light, moving on the wall of my room."

By the turn of the 20th century, interest in this phenomenon had escalated, especially because most observers compared them to the shadow bands seen at eclipses. These observational studies helped astronomers realize that shadow bands are more meteorological than astronomical. Still, searching for these faint and transitory shadows can help you hone your skills as an observer.

Solar eclipses are known to create the atmospheric phenomenon known as shadow bands. Tunç Tezel

The phantom slither

Some years prior to Dufour's 1906 description, Charles J. P. Cave of Petersfield, England, frequently had noticed that when the Sun set over the sharp roof of King's College Chapel at the University of Cambridge, irregular bands of shadow would, for a few seconds, move vertically (perpendicular to their length) up the sunlit walls of his room. The bands would appear when half the Sun set behind the chapel's roof and continue to move as long as the sunlight lasted.

Other observers saw the bands shortly after sunrise, when the Sun was rising above a flat and clear horizon or passing from behind a bald mountain. In most cases, the bands remained sharp until the instant when about a third of the Sun's diameter was above the horizon. The accounts also said that the state of the atmosphere affected the shadow bands' appearance. They moved slowly and stately in calm weather and rapidly in a gusting wind.

Ralph Copeland, director of Dunechet Observatory near Aberdeen, Scotland, gave a highly detailed account of the phenomenon in the March 1880 issue of the *Monthly Notices* of the Royal Astronomi-

Earth's horizon eclipses the Sun twice each day: once at sunrise, and once at sunset. If the horizon is relatively flat and sharp, the Sun is at least two-thirds eclipsed, and the air is still, faint shadow bands may ripple across the landscape opposite the Sun. The author took these images of the Sun setting behind Hawaii's long and smooth Mauna Loa Volcano some 15 miles (24 kilometers) away. Stephen James O'Meara

"Sharp, distant horizons at sunrise and sunset are just as effective in producing this natural atmospheric curiosity."

cal Society. He and his assistant saw the event December 18, 1879, on the great dome's inner wall. The bands, according to Copeland, were about 0.25 inch (0.6 centimeter) broad, almost exactly horizontal, and some 2.5 inches (6cm) apart. "They were produced by the last rays of the Sun," he said, "then setting behind the smooth horizontal ridge of the Hill of Fare, five miles distant." Copeland also noted that the bands ascended at a rate of 1.5 feet (0.5 meters) in a second and had a distinct quivering motion.

Shadow bands often form on plain, light-colored surfaces just before and after totality or annularity during a solar eclipse, but they are hard to capture on film due to the lighting and their motion. This rare still frame of the shadow bands comes from a movie that Dr. Wolfgang Strickling shot near Muzarabani, Zimbabwe, during the June 21, 2001, total solar eclipse. Dr. Wolfgang Strickling

Copeland and his assistant continued to search for these quivering shadow bands during subsequent sunsets, but found their occurrence uncertain and variable. "There are very fine sunsets," Copeland explained, "which do not give a trace of them even on the whitest surface most completely screened from any but the direct light of the Sun. At other times the lines are short, crooked and disconnected, *descending* as well as ascending, forming and disappearing within a few seconds."

To the field

For a week beginning August 20, 2008, I drove to the summit of Kilauea, near my home in Volcano, Hawaii, to look for shadow bands as the Sun set behind the long and smooth slope of Mauna Loa Volcano some 15 miles (24 kilometers) distant. On my first attempt, I parked the car so the Sun's light would pass directly through the driver's side window that I had rolled down. Once the bottom of the Sun touched the long mountain slope, I held up at arm's length a plain sheet of white paper opposite the setting Sun, then watched and waited.

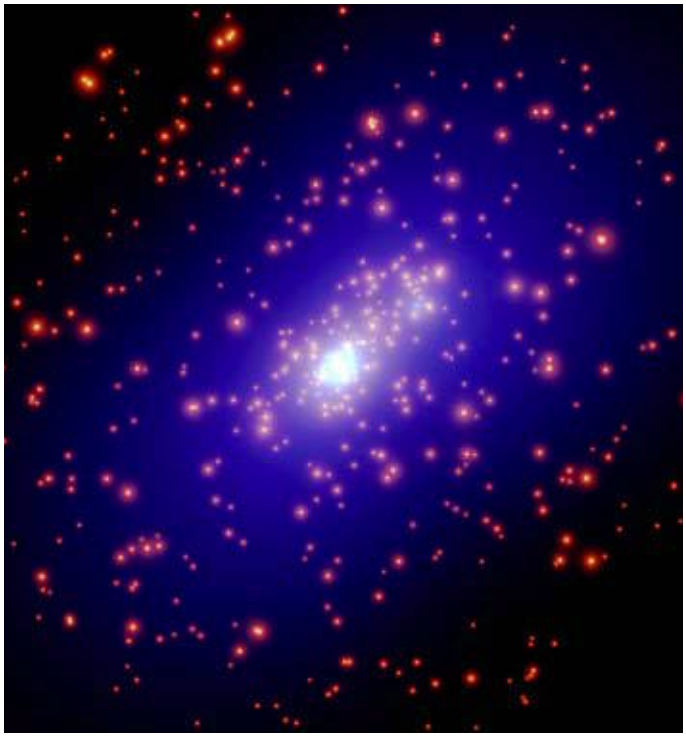
The bands materialized faintly when half the Sun had set behind the mountain and then grew gradually stronger. They were not long snakes of light, but a dancing array of inch-long ovals that swayed back and forth like the shadow of a loose chain-link fence quivering in the wind. The "links" moved both up and down the paper, resembling what happens if you disturb a bamboo curtain. When the Sun was two-thirds covered, the pattern reorganized into long wavering bands of light and shadow — each separated by about 0.5 inch (1cm) — that moved vertically up the sheet at a rate of about an inch per second. The phenomenon faded and then vanished before the entire Sun had set.

The occurrence and appearance of the shadow bands on subsequent days were variable and irregular. On some days, I saw the weakest imaginable shadow agitations. On other days, I looked for the bands in the open air and saw nothing at all. Once, in a parking area protected from wind, I saw a series of long dark waves side-winding up the paper like the classic shadow bands seen during an eclipse. Now I'm interested in your experiences. Send your reports to me at someara@interpac.net.

Martian masochists This month, six volunteers were scheduled to begin 105 days of experimental confinement in a Moscow laboratory that mimics a manned mission to Mars.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews



What's the matter? Using Hubble Space Telescope data, astronomers mapped the dark matter in galaxy cluster CL0024+1654. In this image, dark matter is colored blue and normal luminous matter appears in the form of individual galaxies (colored red). Recent Antarctic research could shed light on dark matter's nature. ESA/NASA/Jean-Paul Kneib (Observatoire Midi-Pyrénées)

Mysterious cosmic rays may originate from dark matter

Scientists using a balloon-borne detector above Antarctica have discovered a previously unknown source of high-energy electrons from space, or cosmic rays. It's possible the source could be dark matter, Jin Chang of Purple Mountain Observatory in China and colleagues reported November 20 in *Nature*.

Cosmic rays constantly bombard Earth. The particles lose much of their energy by the time they traverse the galaxy and Earth's atmosphere. Hence scientists typically detect low-energy cosmic rays at Earth's surface.

While about 124,000 feet (37.8 kilometers) above Antarctica, the Advanced Thin Ionization Calorimeter (ATIC) measured an excess of cosmic rays. Scientists think the electrons must originate from a nearby source about 3,000 light-years away.

Astronomers believe dark matter makes up most of the universe's mass, but no one has directly detected it. One dark matter candidate is the theoretical Kaluza-Klein (KK) particle.

Scientists say the high-energy electrons detected by ATIC could be the result of collisions between KK particles. If true, our solar system may be passing through or near a large clump of dark matter. Other alternatives include an undiscovered black hole or pulsar. Additional detections are needed to determine the source of these high-energy cosmic rays. — **LIZ KRUESI**

18 Hubble sniffs CO_2 in alien air

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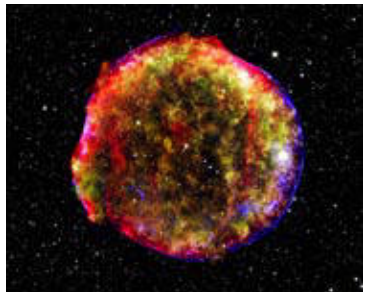
20 Massive glaciers found on Mars

Light echoes reveal Tycho's supernova

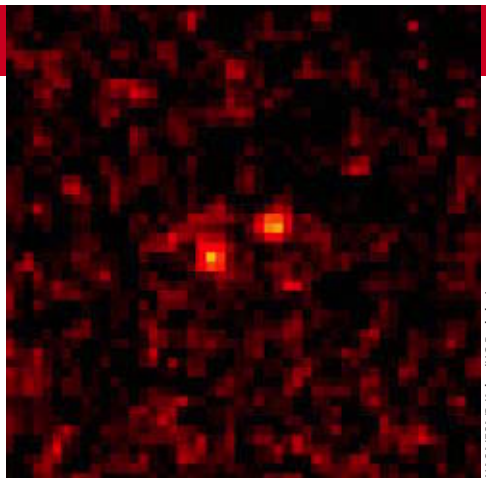
Shortly after Tycho Brahe's supernova exploded in 1572, its light reflected off a nearby dust cloud. Now, more than four centuries later, that light has reached Earth bearing new information about the stellar explosion now known as SN 1572.

The delayed signal, or "light echo," allowed astronomers led by Oliver Krause of the Max-Planck-Institute for Astronomy in Germany to sample light from the original blast. They concluded a white dwarf star exploded in a so-called type Ia supernova to form SN 1572. The team reported its findings December 4 in *Nature*.

By studying a supernova's light output, or spectrum, astronomers can decipher what chemical elements were released in the blast. The astronomers found traces of silicon, sulfur, and iron in the light echo's spectrum, which point to a type Ia supernova. Other clues in the spectrum "provide kinematical details of the explosion," Krause says, such as how spherical the blast was. — **L. K.**

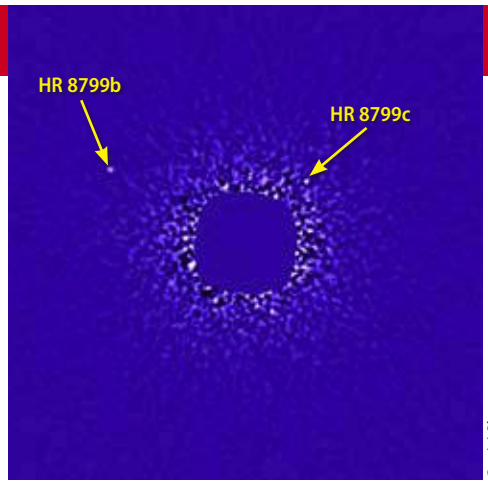


Second sight. Although SN 1572's initial flash reached Earth more than four centuries ago, its "light echo" arrived in 2008, providing a second look at the event. Max-Planck-Institute for Astronomy



NASA/ESA/P. Kalas (UC-Berkeley)

Pixel planet. The Hubble Space Telescope imaged the planet Fomalhaut b. These two pixelated traces show the same planet 21 months apart.



Gemini Observatory

First family. Telescopes on Hawaii's Mauna Kea captured three planets around the same star. The innermost of the trio is not visible in this image.

Astronomers capture first exoplanet images

Two teams announced a major advance in exoplanet science: the first confirmed direct images of planets in other solar systems. One team unveiled the first visible-light portrait of an exoplanet. Another group produced the first snapshot of multiple planets. Both teams reported their findings November 28 in *Science*.

The visible-light image shows a planet orbiting the star Fomalhaut, 25 light-years from Earth. The planet, officially named Fomalhaut b, is similar in mass to Jupiter and orbits from its star at about 119 times the Earth-Sun distance.

Hawaii's Gemini North and Keck 2 telescopes caught infrared-light images of three planets circling the star HR 8799, 129 light-years from Earth. The planets formed about 60 million years ago and are still glowing from heat released during their formation. They are 7 to 10 times Jupiter's mass, and their orbits lie at distances 24, 38, and 68 times the Earth-Sun distance.

The images make the exoplanets seem all the more real. "When astronomers discover new planets around a star, all we see are wiggly lines on a graph of the star's velocity or brightness," says HR 8799 team member Bruce Macintosh of California's Lawrence Livermore National Laboratory. "Now we have an actual picture showing the planets themselves." — **DANIEL PENDICK**

Study supersizes Jupiter's core

A new computer simulation suggests Jupiter's rocky core may be more than twice as massive as scientists previously thought. University of California at Berkeley geophysicist Burkhard Militzer and colleague William B. Hubbard of the University of Arizona's Lunar and Planetary Laboratory in Tucson reported the study's findings November 20 in *The Astrophysical Journal Letters*.

Most of Jupiter's bulk consists of hydrogen and helium gas. The simulation calculated the physical properties of the gases at increasing temperatures, pressures, and densities all the way to the planet's core.

The researchers concluded that Jupiter's core is a rocky body 14 to 18 times Earth's mass that probably also contains layers of metals and ices. Previous computer models predicted either no core or one around 7 Earth masses.

"The results support the hypothesis that Jupiter formed by core-accretion, where a large planetary core forms first and the gas is attracted by gravity to it later," Militzer says. — **D. P.**

Core issues. Deep beneath Jupiter's swirling gaseous outer layers lies a core of metal, rock, and ice that may be more massive than scientists thought.

NASA/ESA/ I. de Pater and M. Wong (UC-Berkeley)

QUICK TAKES

SPANISH STARS

Universo, a daily astronomy radio program in Spanish produced at the University of Texas at Austin McDonald Observatory, aired its 5,000th episode December 7.

OLDIE BUT GOODIE

NASA released a newly restored historic image November 13. Shot by the Lunar Orbiter 1 in 1966, the photo shows Earth rising over the lunar surface.

YOU DRIVE

Russia's robotic resupply ship Progress, despite a new computer system, had to dock with the International Space Station in manual mode November 30.

GLIDE PATH

NASA's asteroid-bound Dawn spacecraft shut down its propulsion system November 20 and glided to Mars for a gravity boost to the asteroid belt.

OCEANS OF EVIDENCE

The Mars Odyssey orbiter's gamma-ray spectrometer discovered subsurface evidence of an ancient ocean that may have covered one-third of the planet.

INDIA'S LUNAR PROMISE

The Indian Space Research Organisation says its astronauts could walk on the Moon by 2020. ISRO chairman G. Madhavan Nair made the claim December 1 at a public lecture in Ahmedabad.

HAVE A SAFE TRIP

A magnetic-field generator weighing less than 700 pounds could protect astronauts from space radiation on long journeys, European researchers reported November 4 in *Plasma Physics and Controlled Fusion*.

SORRY FOR THE MESS

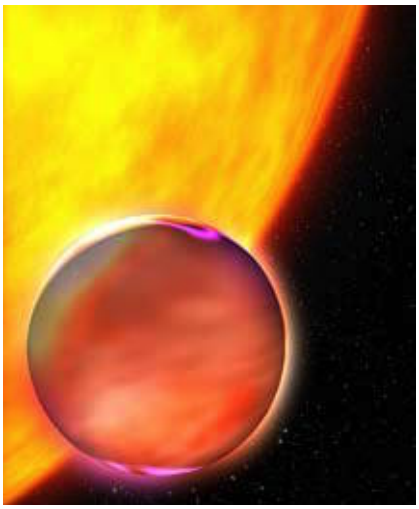
Roscosmos, Russia's space agency, agreed November 7 to pay $4,000 to a Siberian villager after an 11-foot (3.5 meters) rocket fragment fell on his land.

CHANG'E LUNAR SEQUEL

China announced November 13 it would launch Chang'e-2, a sequel to 2007's Chang'e-1 lunar probe, by 2012.

NASA TEACHES TEACHERS

NASA unveiled its Endeavour Science Teaching Certificate Project November 14. Two hundred teachers awarded fellowships will learn how to use NASA research in the classroom.



NASA/ESA/G. Bacon (STScI)

Smells like life. The "hot Jupiter" HD 189733b, shown in this artist's impression, can't support earthlike life. But detecting carbon dioxide in its searing atmosphere bodes well for finding more habitable worlds elsewhere.

Hubble sniffs CO_2 in alien air

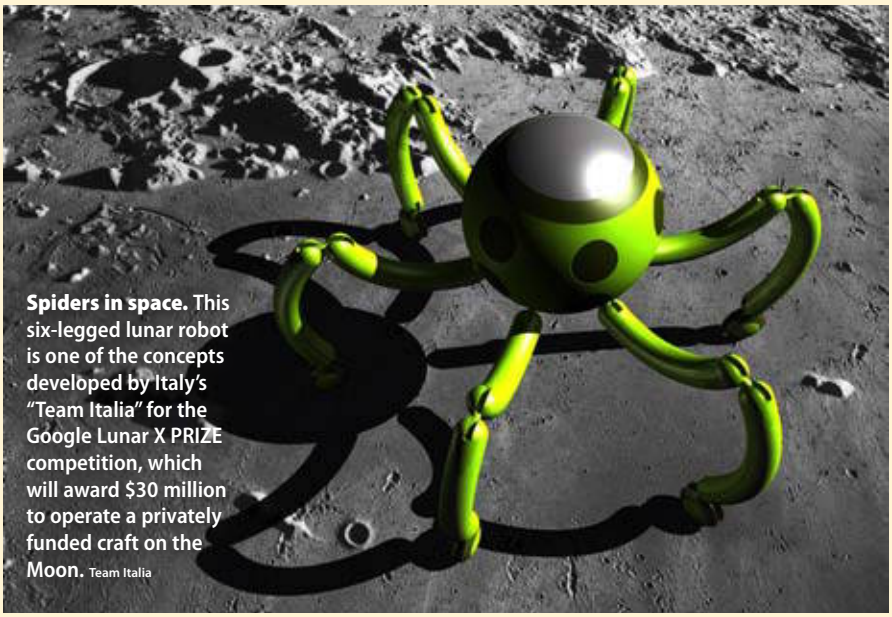
Astronomers found carbon dioxide — a possible marker for biological activity — on a planet outside our solar system for the first time. The planet is hostile to life as we know it, but the discovery bodes well for searches on more habitable worlds.

A team of researchers led by Mark Swain of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, used the Hubble Space Telescope to detect the clear, odorless gas. They found it in the atmosphere of a planet, HD 189733b, orbiting a star 63 light-years from Earth. HD 189733b is a searingly hot gas giant about Jupiter's mass.

The researchers used Hubble to gather infrared light emitted by the planet. The telescope's infrared spectrometer separated the light into its component wavelengths, or spectrum. The spectrum contained evidence of carbon dioxide.

On planets with moderate climates similar to Earth's, carbon dioxide is among the tracers produced by plants and animals. Detecting the gas on HD 189733b means it can be found on other exoplanets, too. Additional biological indicators include water, methane, and oxygen.

JPL's Gautam Vasisht detailed the team's findings November 19 at the Molecules in the Atmospheres of Extrasolar Planets conference in Paris. — **D. P.**



Spiders in space. This six-legged lunar robot is one of the concepts developed by Italy's "Team Italia" for the Google Lunar X PRIZE competition, which will award $30 million to operate a privately funded craft on the Moon. Team Italia

NASA seeks new space partners

The Apollo Moon missions of the 1960s depended on government-furnished equipment, bought and paid for by the U.S. taxpayer. But a revolutionary new strategy in preliminary development at NASA's Johnson Space Center in Houston may tap the private marketplace to contribute important elements of lunar exploration. Commercial companies may provide a range of critical services, including communications, navigation, and cargo transport.

Already, there's money to be made from lunar exploration, in the form of the Google Lunar X PRIZE. The competition offers up to $30 million in winnings to privately funded teams that can operate a Moon rover, which must travel 1,640 feet (500 meters) and send video, images, and data back to Earth. Sixteen teams registered by the end of 2008. The first team to win by the close of 2012 gets a $20 million grand prize. The second crew to complete the mission receives $5 million. Teams will also compete for $5 million in miscellaneous bonus prizes.

As privately funded Moon robots vie for Google's purse in coming years, some will win and others will be left behind. But if visionary NASA officials have their way, the winners of the Google prize will be the vanguard of an invasion of small lunar robots. They could number in the dozens or more in the years leading up to 2020, when NASA hopes to again land humans on the Moon.

First off would be demonstrations of local lunar resource extraction, such as harvesting oxygen from the soil. Also vying for NASA's dollars could be commercially developed technologies to insulate cryogenic rocket fuel tanks and demonstrate navigation for precision landings. To be included in the lunar landing design, companies would need to demonstrate the techniques by 2013 or 2014, on current schedules.

Another type of service the marketplace could provide for lunar exploration is a privately run constellation of relay satellites and navigation beacons near the Moon. Again, such payloads would also need to be tested early in the next decade, so the satellites would be in place when human lunar surface exploration resumes.

In imagining how such non-government Moon missions could be created, space analysts realized NASA already has a model in place. The program, called "commercial off the shelf," or COTS, covers transportation from Earth into orbit — particularly to the International Space Station. COTS provides seed money to private companies.

Intelsat also offers a template for developing a Moon communications services company. The world's largest commercial satellite communications services provider, Intelsat receives government-backed loans based on promised future service purchases. Intelsat, along with COTS, Google's Lunar X PRIZE, and other efforts to come, may prove to be the "partnerships made in heaven" for NASA's next decade of space exploration.
— **JAMES OBERG**

ESO/APEX/DSS2/SuperCosmos/Deharveng(LAM)/Zavagno(LAM)

Star bubble. In this radio telescope image, radiation from the bright central star blows a "bubble" in the surrounding cold gas (blue).

High-altitude telescope tunes into star birth

European astronomers captured a dramatic snapshot of star birth in cold interstellar gas, thanks to the 12-meter Atacama Pathfinder Experiment (APEX) telescope. APEX, a radio telescope located at Llano de Chajnantor Observatory in Chile's Atacama Desert, probed the gaseous region RCW120, some 4,200 light-years from Earth toward the constellation Scorpius.

In the new portrait, a hot massive star emits intense ultraviolet radiation, which tears apart hydrogen atoms into an electrically charged (ionized) gas. The ionized gas has formed a bubble about 10 light-years across. The bubble's advancing edge triggers gas to collapse into clumps and ignite new stars.

Despite the young star's radiation, the gas in RCW120 is relatively frigid — around –418° Fahrenheit (–250° Celsius). Llano de Chajnantor, at an altitude of 16,745 feet (5,104 meters), is one of a handful of locations on Earth where astronomers can observe such cold clouds by tuning into the so-called submillimeter wavelengths. The submillimeter portion of the spectrum, where cold gas emits energy, lies just beyond infrared wavelengths. **— D. P.**

Space sniffer

During space shuttle Endeavour's November 14–30 mission, astronauts installed an experimental "ENose" to sniff the space station air for potentially harmful chemicals.

Fireball flares over western Canada

At about 6:26:45 P.M. local time November 20, people across Alberta, Saskatchewan, and western Manitoba witnessed a brilliant exploding meteor, or fireball, that lit up the darkening sky. Amateurs with digital devices as well as professionals using all-sky video cameras captured the spectacular sight.

A team led by University of Calgary planetary scientist Alan Hildebrand and other researchers immediately went out to search wheat fields and ranch land for meteorite fragments, as did many amateur space-rock hunters. "We speculate that hundreds of fragments have already been removed from the site, mostly undocumented," says Canadian amateur astronomer Richard Huziak.

Ellen Milley, a graduate student working with Hildebrand, found the first fragment on a frozen pond exactly one week after the fireball. Amateur space-rock hunters from Drayton Valley, Alberta, found a fragment weighing 29 pounds (13 kilograms) on a farmer's land and later returned it to the landowner. It was the largest fragment discovered to date. **— D. P.**

Richard Huziak

Fireball find. Amateur astronomer Richard Huziak found this fragment of a meteorite that exploded over Canada November 20. The sample measures about 2 inches across (5 centimeters) on its long axis.

BRIEFCASE

Megascope is top pick for Europe

ASTRONET, composed of astronomers from 28 European countries, announced November 25 that its top-priority project for the next 20 years is the proposed 42-meter European Extremely Large Telescope. The instrument would be the largest optical telescope ever built, exploring the sky in visible and infrared light. — D. P.

How to eyeball Ares on iTunes

NASA now posts video progress reports on iTunes detailing ongoing work on the Ares launch system. The Ares I crew launcher and Ares V cargo booster will replace the space shuttle fleet by 2015. To download the 10 to 15 minute videos and subscribe to the quarterly updates, search the Apple iTunes Store online for "Ares HD podcast." — D. P.

Exposing a crater

Geologists at the University of Alberta reported a new way to locate small meteorite craters hidden under dense tree cover. In the December 2008 issue of *Geology*, the scientists explain how they used commercially available aerial survey data to strip the land of its forest canopy and expose a 118-foot-wide (36 meters) crater in an Alberta forest. Previously discovered from the ground by hunters, the crater has yielded some 74 iron meteorites so far. — D. P.

25 years ago in *Astronomy*

March 1984

Astronomy's March 1984 issue featured an article by Robert Burnham about the Infrared Astronomical Satellite (IRAS). In "IRAS and the infrared universe," Burnham described the reams of new data IRAS harvested as NASA surveyed nearly the entire infrared sky for the first time.

IRAS launched in January 1983. It ran out of coolant for its sensitive electronic detectors after 10 months and ceased observations.

Despite the observatory's short lifetime, IRAS mapped 96 percent of the sky at four infrared wavelengths and observed more than 200,000 galaxies, stars, star clusters, and other targets. IRAS also discovered starburst galaxies and was the first satellite to find a comet.

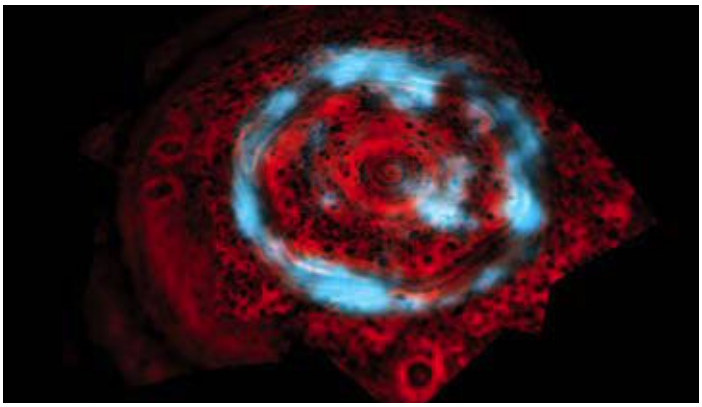
March 1999

10 years ago in *Astronomy*

In March 1999's "King of the Mountain," Govert Schilling introduced readers to the European Southern Observatory's Very Large Telescope (VLT). The VLT consists of four identical 8.2-meter telescopes located on Cerro Paranal in Chile's Atacama Desert. The huge instrument began operation in 2001.

"When completed, the VLT will be the most powerful observatory in the world," Schilling wrote, "and with its diverse collection of astronomical detectors, including high-resolution electronic cameras and multi-object spectrographs, it will help astronomers answer their most fundamental questions about the origin, evolution, and structure of the universe." **— MEGAN McCHAIN**

Lost and found Amateur astronomers tracked a $100,000 tool bag orbiting Earth after shuttle astronaut Heidemarie Stefanyshyn-Piper lost it during a space walk November 18.



Color drapes. Saturn glows with the light of an infrared aurora (blue) that drapes over the planet's north pole. The planet's atmosphere appears reddish in this composite view taken at two infrared wavelengths. NASA/JPL University of Arizona

Saturn shows off odd aurora

Saturn's north pole sports a new and unexpected type of aurora, astronomers reported November 13 in *Nature*. The odd aurora glows in infrared light and has no known counterpart in the solar system. "It's not just a ring of aurorae like those we've seen at Jupiter or Earth," says Tom Stallard of the University of Leicester, England. "This aurora covers an enormous area across the pole."

Earth's aurorae arise when charged particles in the solar wind stream into our atmosphere along magnetic field lines. This process plays a role at Jupiter and Saturn, too, but those planets can also produce aurorae from charged particles trapped in their enormous magnetospheres. The newly discovered Saturn aurora doesn't fit into either category.

Stallard and his team discovered the aurora on Cassini images taken with the spacecraft's visual and infrared mapping spectrometer. The glow sometimes fills the north polar region from 82° latitude to the pole, yet the infrared glow changes constantly and even disappears occasionally. Theories on what causes Saturn's aurora predict this region should be empty. — **RICHARD TALCOTT**

Colliding clouds forge planet building blocks

Colliding gas clouds may forge the tiniest building blocks of rocky planets, according to Spitzer Space Telescope researchers. Their findings, slated to appear in *The Astrophysical Journal,* provide new insight into the early stages in rocky planet formation.

William Forrest of the University of Rochester, New York, and colleagues studied five young planet-forming systems, consisting of stars surrounded by swirling disks of gas and dust. The researchers detected crystals of the minerals cristobalite and tridymite.

Cristobalite and tridymite are forms of quartz. Such crystalline dust grains stick together to form larger particles, which lump together into even larger particles. This process builds planets.

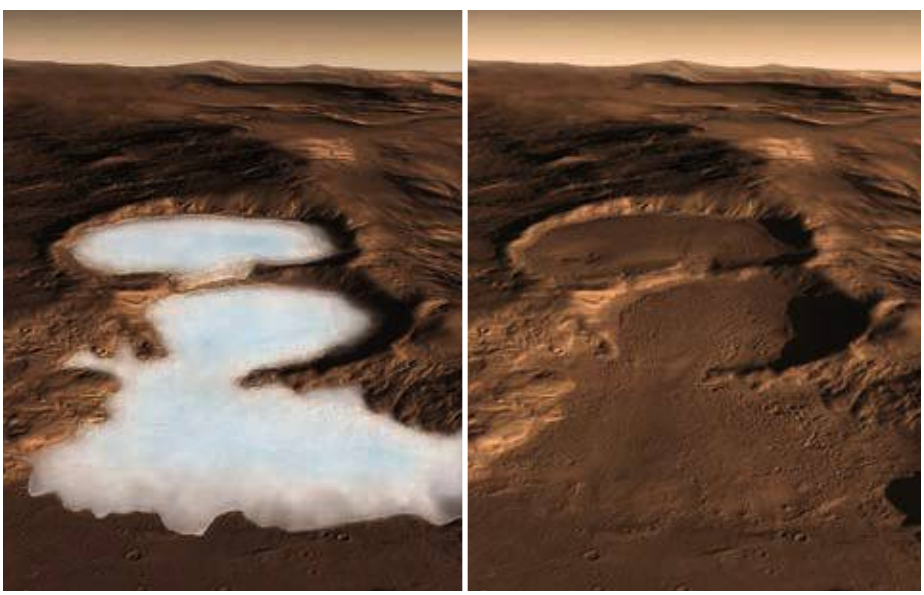
However, cristobalite and tridymite form at temperatures and pressures higher than those typical in planet-forming disks. The researchers think the crystals may be forged within shock waves unleashed when gas clouds collide inside the disk— **D. P.**

Massive glaciers found on Mars

NASA's Mars Reconnaissance Orbiter (MRO) has revealed vast glaciers at much lower latitudes than any ice previously identified on the Red Planet. "Altogether, these glaciers almost certainly represent the largest reservoir of water ice on Mars that is not in the polar caps," says John W. Holt of the University of Texas at Austin. "Just one of the features we examined is 3 times larger than the city of Los Angeles and up to half a mile thick." Holt and his colleagues published their findings November 21 in *Science*.

MRO's ground-penetrating radar instrument found evidence for the glaciers underneath protective blankets of rocky debris. The rocky cover may have allowed the glaciers to remain frozen at middle latitudes since the end of the last ice age on Mars.

The ice extends for dozens of miles beneath aprons of rocky debris sloping away from taller geographic features, like mountains or cliffs. MRO probed the aprons with radio waves, which reflect off buried structures. The radio waves passed through the debris apron, reflected off a deeper layer, and returned to the craft with minimal loss of power. Thick ice under a thin rock cover explains this pattern.



Cold spell. In these computer-generated images, ice collected in low-lying craters (left) during a past martian ice age. A thin layer of rock and dust now prevents the ice from evaporating (right). Buried glaciers may represent Mars' greatest freshwater reservoir. NASA/Caltech/JPL/UTA/UA/MSSS/ESA/DLR

The glaciers lie at 35° to 60° in both hemispheres. This suggests the ice formed during a previous ice age, when cold conditions spread toward the equator from the poles. — **D. P.**

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Spacecraft flybys and the Moon's orbit aren't following predictions. Whatever is causing this could usher in a new theory of gravity.

by John D. Anderson

In 1687, Sir Isaac Newton (1642–1727) published his *Philosophiae Naturalis Principia Mathematica,* in which he detailed his law of gravity. For centuries Newton's gravity mostly matched observation, but it wasn't perfect. Some 230 years later, in 1916, Albert Einstein (1879–1955) published his general theory of relativity. His theory resolved several long-standing questions about the way gravity works. But it now seems general relativity might not have answered every question. Over the past few decades we've observed several curious gravity effects. To resolve these "anomalies," we may again need to revise gravitational theory.

Mercury's orbit, explained

In the mid-19th century, Jean Joseph LeVerrier (1811–1877) noticed discrepancies in the observed positions of the planet Mercury. This "Mercury anomaly" involved a subtle aspect of planetary orbits.

In a two-body orbit — the Sun and a planet — Newton's laws predict that a planet will follow an elliptical orbit. However, when astronomers take the gravitational attractions of other planets into account, this is no longer true. Instead, one can assume the planets do follow elliptical orbits, but the ellipse itself rotates in space because of the effect of other planets.

Mercury exhibits this "orbital rotation" best in what is called the precession of Mercury's perihelion (closest approach to the Sun). Newton's theory says Mercury's orbit should precess 531 arcseconds per century, or that its perihelion should return to the same location in the sky roughly every 244,000 years. LeVerrier couldn't reconcile telescopic observations of Mercury's position with this Newtonian prediction. Mercury's elliptical orbit rotates too rapidly. In 1882, American astronomer Simon Newcomb (1835–1909) refined LeVerrier's calculations and confirmed that Mercury's orbit was indeed rotating too rapidly, by about 43 arcseconds per century, or 8 percent faster than Newtonian mechanics predicted.

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The theory of gravity has been rewritten many times throughout history, and we may be on the brink of another such moment. A number of astronomical oddities are showing astronomers they understand less about gravity than they thought. The astronomical unit, a supposed constant, seems to be increasing; a few spacecraft have sped up following Earth flybys; and the Pioneer spacecraft are closer to us than they should be. What's causing these gravity anomalies?
Don Dixon for *Astronomy*

know about GRAVITY!

This lunar laser reflector array is one of three delivered to the Moon's surface around 1970 by Apollo astronauts and the robotic Lunikod lander. Astronomers use the reflectors to determine the distance to the Moon to a precision of about 1 centimeter. NASA

Scientists didn't have an acceptable explanation for Mercury's precessing orbit until Einstein published his final version of general relativity. But the theory solved the Mercury anomaly even though Einstein may not have been aware of problems with Mercury's motion when developing his theory.

Today, almost a century later, we may be on the verge of another shift at whose center lies, as before, Newtonian physics.

Mysterious Moon movements

Astronomers have understood the Moon's motion around Earth since Newton published his theory of gravity in 1687. If scientists need extreme precision, they turn to general relativity, which reigns as scientists' best understanding of gravity. But something seems to be missing.

Around 1970 Apollo astronauts and the robotic Lunikod lander delivered laser reflectors to the Moon's surface. Astronomers use these reflectors to track the Moon's position to an accuracy of about a centimeter, or two parts in 100 billion.

After analyzing 38 years of precise distance data between observatories on Earth and these lunar reflectors, James G. Williams of Caltech's Jet Propulsion Laboratory (JPL) found that the Moon's orbit around Earth is becoming more elliptical. Williams reported in 2006 that the distance difference between the Moon's farthest and closest approach to Earth is increasing unexpectedly by about 0.2 inch (6 millimeters) per year. Some people, however, think this anomaly isn't something to worry about. Nongravitational forces act on the Moon's orbit as a result of internal tidal friction in both Earth and the Moon.

After accounting for changes expected from tidal friction, Williams still has a residual change in the Moon's orbit that he can't explain. We expect the eccentricity to change because of tidal friction, but Williams discovered that it is increasing too much — by a factor of about three. We don't have any clear explanations for this change of the Moon's orbit.

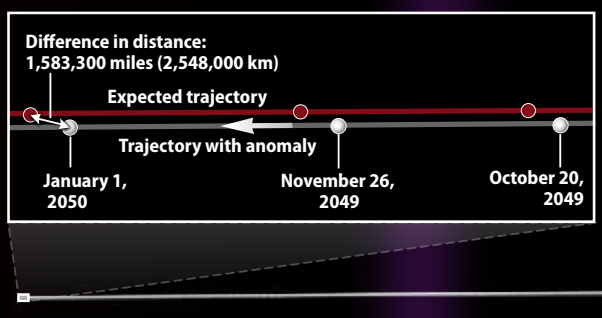
Astronomical Unit inflation

In 2004, E. Myles Standish of JPL reported that the value of the solar system's length scale — the astronomical unit (AU) — seems to be increasing, thus effectively increasing the Sun's gravitational attraction.

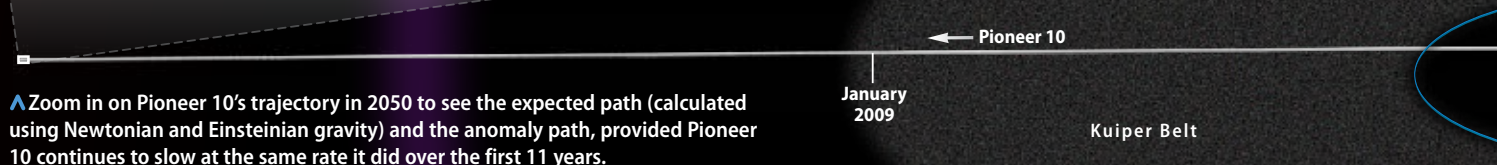
The AU — the average distance between Earth and the Sun — is considered an astronomical constant. Scientists measure the distance using radio ranging techniques between Earth and the planets. Astronomers know its value to 11 decimal digits, making the AU the most accurately measured astronomical constant.

We determine the distance to the Moon with laser ranging, but because the

The unexplained Pioneer oddity



Pioneers 10 and 11 are closer to the Sun than they should be, by Newtonian gravity and general relativity calculations. Something is decelerating both spacecraft the same amount, even though they are leaving the solar system in opposite directions. Astronomers may need a revised version of gravity to explain this Pioneer anomaly. *Astronomy:* Roen Kelly after data from John D. Anderson



^ Zoom in on Pioneer 10's trajectory in 2050 to see the expected path (calculated using Newtonian and Einsteinian gravity) and the anomaly path, provided Pioneer 10 continues to slow at the same rate it did over the first 11 years.

planets are too far away for that, we use radio waves beamed to spacecraft. While the lunar distance can be measured to an accuracy of about a centimeter, the accuracy of radio ranging is about 3 to 33 feet (1 to 10 meters). Three radio transponders, similar to those aboard aircraft, have been landed on Mars. Those transponders arrived aboard the Viking 1 lander (July 20, 1976, to November 13, 1982), the Viking 2 lander (September 3, 1976, to April 11, 1980), and the Pathfinder spacecraft (July 4, 1997, to October 7, 1997).

The NASA Deep Space Network (DSN) located in California, Australia, and Spain can make distance measurements between the landers and Earth. However, the transponders are not passive devices like the laser reflectors — they depend on spacecraft power.

The martian lander data acquired between 1976 and 1997 provide a valuable database for exploring orbital motions on a planetary scale.

Georgij Krasinsky and Victor Brumberg at the Institute of Applied Astronomy in St. Petersburg, Russia, used these measurements and other positional data compiled by Elena Pitjeva, also of the Institute of Applied Astronomy, for a total of some 204,000 observations. Krasinsky and Brumberg reported in 2004 that the AU was increasing at a rate of 49 feet (15m) per century, give or take a few meters.

In 2005, Pitjeva published an even more detailed analysis of 317,000 observations extending from 1913 to 2003. Her analysis is consistent with general relativity and represents one of the best tests available of the overall applicability of Einstein's theory to gravitational systems.

Pitjeva's results set the distance scale within the solar system, the AU, to an accuracy of 1 meter. At this level of precision, the positional data spanning 1967 to 2003 show the AU increases with time.

The latest measurements by Pitjeva and Standish suggest the AU is increasing about 23 feet (7m) per century. However, the AU should not change at all!

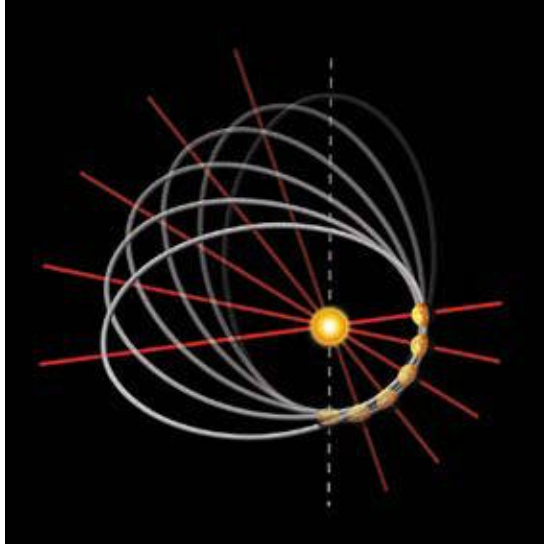
The Pioneer anomaly

Weird gravity effects are not limited to only celestial bodies in the solar system. Pioneers 10 and 11, now escaping our solar system in opposite directions, aren't where we expected them to be.

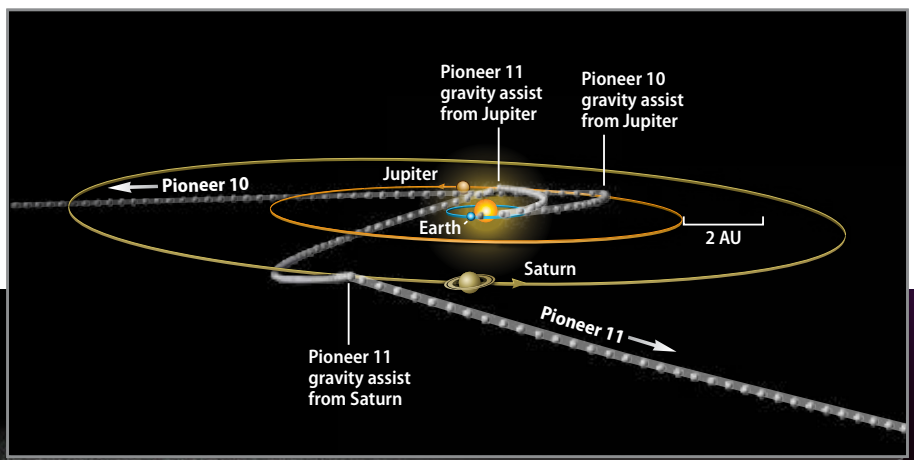
Pioneer 10 launched March 2, 1972, and flew past Jupiter December 4, 1973. As a result, Jupiter's gravity threw it out of the solar system. Pioneer 10 is now way beyond the major planets, at a distance of 96 AU from the Sun, and traveling at a rate of 2.5 AU per year. At its present rate, it will reach the region of the star Aldebaran in about 2 million years.

Pioneer 11 launched April 6, 1973. As it flew past Jupiter December 2, 1974, Jupiter's gravity placed it on a path to Saturn, which it reached September 1, 1979. Saturn's gravity threw Pioneer 11 out of the solar system. Pioneer 11 is closer to the Sun, at a distance of 75 AU, than Pioneer 10, and traveling more slowly, at a rate of 2.4 AU per year, toward the constellation Aquila. It will pass near Lambda (λ) Aquila in about 4 million years.

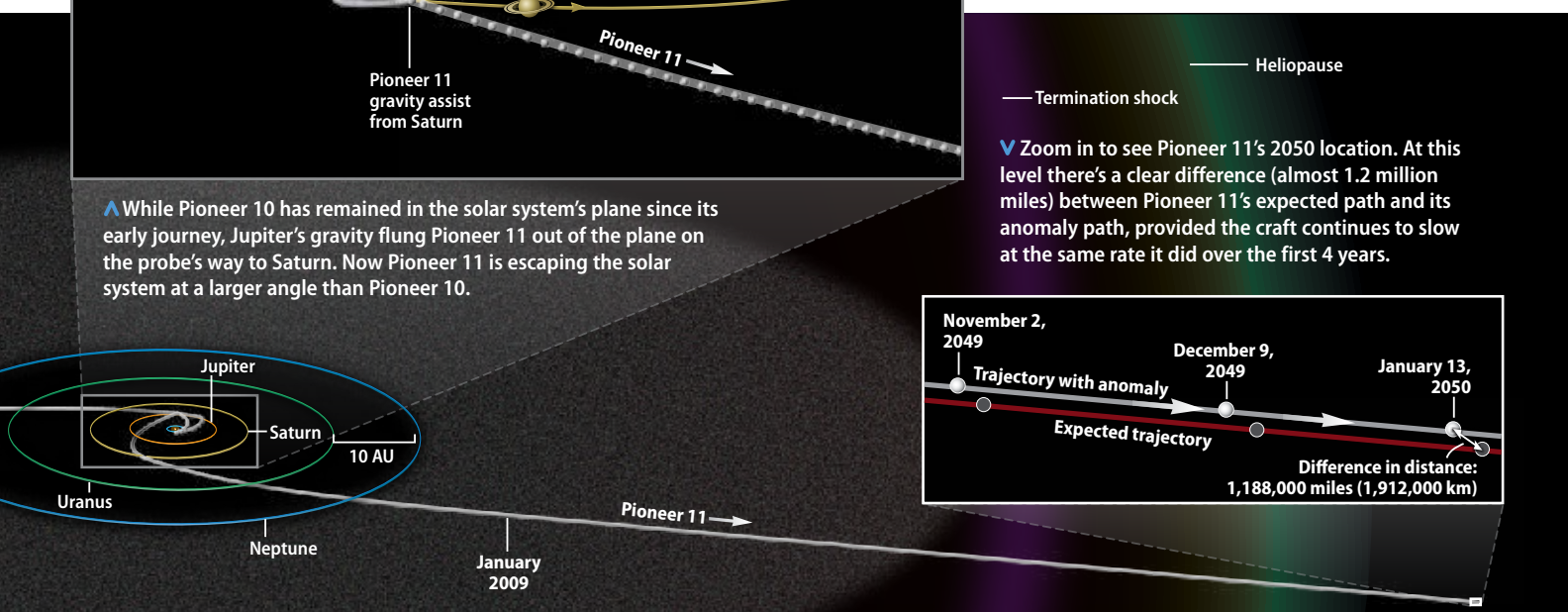
DSN stations tracked the motions of the two spacecraft before they were too far away to communicate with. In the late



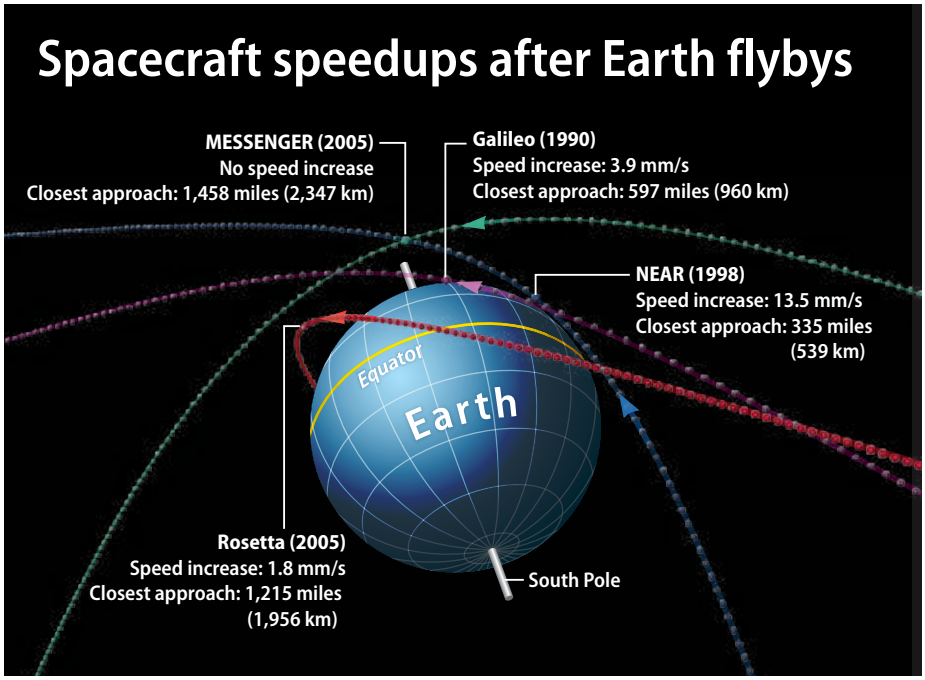
The perihelion of Mercury advances 531 arcseconds per century, more than Newton predicted. However, Einstein's general relativity explained this Mercury anomaly. *Astronomy*: Jay Smith



∧ While Pioneer 10 has remained in the solar system's plane since its early journey, Jupiter's gravity flung Pioneer 11 out of the plane on the probe's way to Saturn. Now Pioneer 11 is escaping the solar system at a larger angle than Pioneer 10.



∨ Zoom in to see Pioneer 11's 2050 location. At this level there's a clear difference (almost 1.2 million miles) between Pioneer 11's expected path and its anomaly path, provided the craft continues to slow at the same rate it did over the first 4 years.



When the Galileo, Near Earth Asteroid Rendezvous (NEAR) Shoemaker, and Rosetta spacecraft flew by Earth for a gravity assist, each sped up more than astronomers predicted. While these increases were small (on the order of a few millimeters per second), they're still real effects. The MESSENGER spacecraft, however, flew by Earth at a greater distance and showed no speed increase. *Astronomy:* Roen Kelly

1990s, my colleagues Michael Martin Nieto of Los Alamos National Laboratory, Slava Turyshev and Eunice Lau of JPL, and Philip Laing and Anthony Liu of The Aerospace Corporation and I analyzed the DSN data recorded over an 11-year period for Pioneer 10 and a 4-year interval for Pioneer 11.

The tracking data showed that, in 1998, the Pioneer 10 spacecraft was about 36,000 miles (58,000 kilometers) short of what we expected, based on the laws of motion given by Newton and Einstein. When we published our results in 1998, we noted that this discrepancy was most likely caused by some spacecraft-related force that we had not accounted for, or possibly by an unknown bias in the data itself. However, over the years neither we nor anyone else has found a satisfactory explanation for the entire discrepancy.

The situation with Pioneer 11 is similar. From the almost 4 years of tracking we have analyzed so far, we have determined the spacecraft is about 3,700 miles (6,000 km) short of its predicted distance. It is as if something is putting the brakes on both spacecraft by just the right amount that they both change their speed the same amount in the same interval of time.

Unfortunately, we couldn't test the Pioneer anomaly with the Voyager spacecraft, which also are escaping from the solar system. The Voyager spacecraft continuously jet gas to keep them stabilized. This jetting spoils them as precision probes of solar system gravity.

The best opportunity for a test is the New Horizons spacecraft that launched toward the Pluto system January 19, 2006. It flew past Jupiter February 28, 2007, and is now in a spin-stabilized mode, like the Pioneers, on its way to a rendezvous with Pluto in July 2015. Unfortunately, unlike the Pioneers, it was never designed for precision tracking of its orbital path. Perhaps we can learn something about the Pioneer anomaly from New Horizons' limited tracking system by 2010 or 2011.

They both change their speed the ***same amount*** *in the* ***same interval of time.***

Oddball orbits

JPL scientists James K. Campbell, John E. Ekeland, Jordan Ellis, and James F. Jordan and I reported in the March 7, 2008, issue of *Physical Review Letters* on anomalous orbital energy changes of six spacecraft that flew by Earth for gravity assists to reach their target bodies. These changes do not obey Newton's law of gravity.

We first noticed the anomaly while working with DSN tracking data from Galileo's December 1990 Earth flyby. The spacecraft was approaching Earth at a speed of approximately 29,470 feet per second (8,981 meters per second) at a distance of about 1.2 million miles (2 million km). After accounting for small and well-known gravitational effects from the Moon, Sun, and planets, we expected the same speed when leaving Earth at a comparable distance. However, the spacecraft's speed was too fast. The excess speed was small, about 0.16 inch per second (4 millimeters per second), but it was in the data. We decided to wait for more scheduled Earth flybys to see if they, too, would show unusual speed changes.

The next opportunity occurred 2 years later when the Galileo spacecraft again flew past Earth. This time Galileo dipped into the upper regions of Earth's atmosphere, making any attempt to measure small gravitational effects futile.

The next flyby, by the Near Earth Asteroid Rendezvous (NEAR) Shoemaker spacecraft in January 1998, did indeed show an increase in speed. It was about 3 times larger than Galileo's, or 0.53 in/s (13.5 mm/s). We were stumped. What could be causing these spacecraft to gain energy and increase their speed? Scientists observed the effect yet again with the Rosetta spacecraft in March 2005, this time with an anomalous speed increase of about 0.08 in/s (2 mm/s).

After the *Physical Review Letters* article was published, Rosetta flew by Earth for another gravity assist at an altitude of 3,290 miles (5,295 km) November 13, 2007. It appears nothing affected Rosetta's speed on this flyby. Rosetta will fly by Earth one last time November 13, 2009, before proceeding to its ultimate target, Comet Churyumov-Gerasimenko.

The Juno spacecraft, scheduled for launch to Jupiter in August 2011 and with an Earth gravity assist in October 2013, may offer the best near-term opportunity for observing this effect, if it is real.

Something other than gravity?

These anomalies have not gone unrequited. Astronomers have tried to tie in the anomalous speed changes with understood effects. Many believe heat radiating from the Pioneer spacecraft may account for the distance discrepancy. Some researchers have claimed up to 70 percent of the anomaly can be attributed to thermal emissions. If thermal emission is the cause, then as the power source cooled, the rate the spacecraft were slowing should have decreased. However, this is not what astronomers have observed. The rate at which the Pioneers have been slowing has remained essentially constant for 11 years.

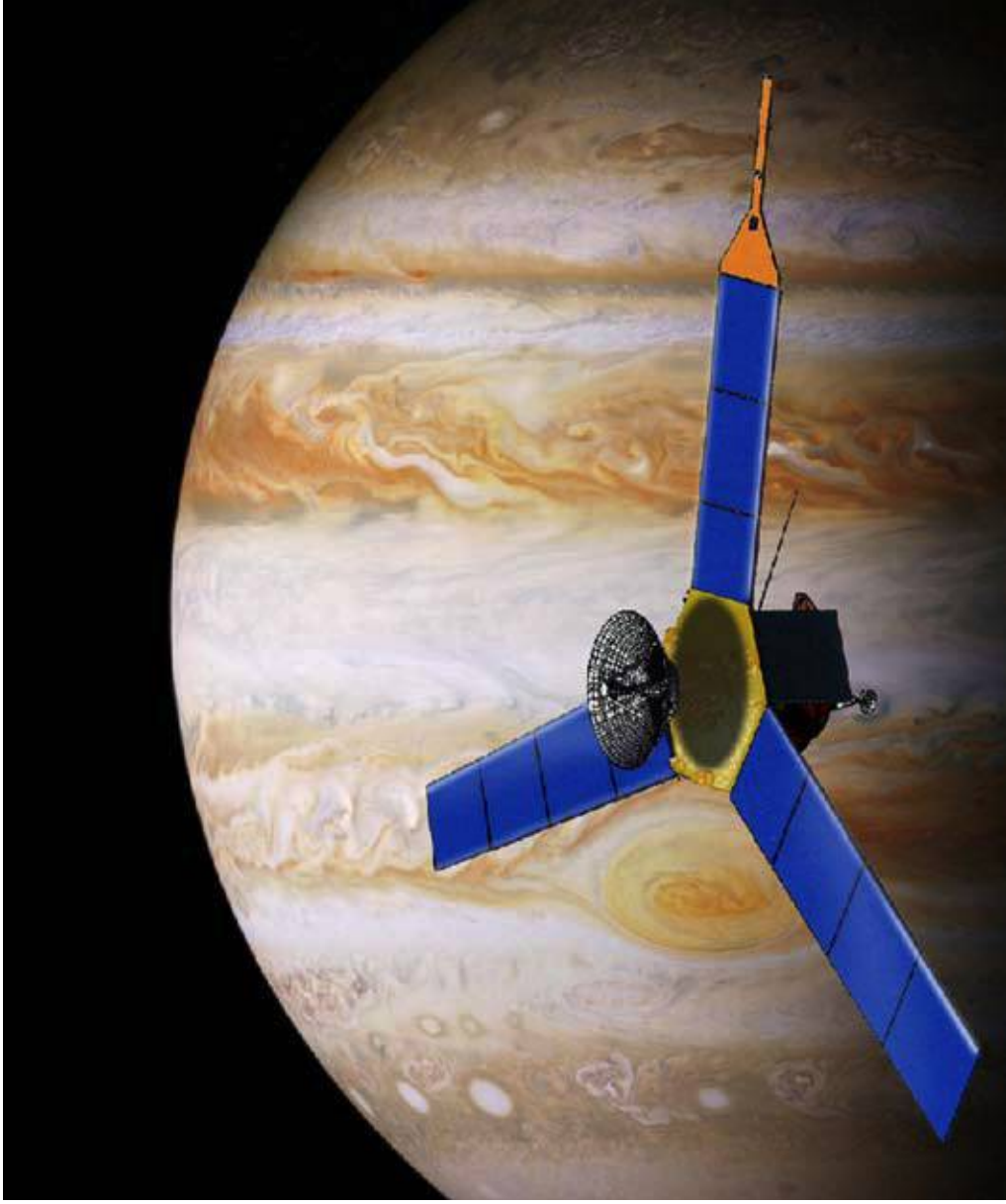
In 2006, Claus Lämmerzahl and Hansjörg Dittus of the University of Bremen and Oliver Preuss of the Max-Planck-Institute for Solar System Research reported that they studied and dismissed a number of other possible explanations for both the Pioneer and Earth-flyby anomalies. Some possible explanations include Earth's atmosphere, ocean tides, solid Earth tides, spacecraft charging, magnetic moments, Earth albedo, and solar wind. None of these possibilities could account for more than 10 percent of the total flyby anomaly, and most were at least 1,000 times too small to affect the anomaly.

A new physics?

Although scientists suspect all these solar system anomalies have mundane explanations, no one has identified one clear source. One thought is that a new physics will explain these observed gravity mysteries. Maybe astronomy is already experiencing a transformation to a new physics, or at least a new theory of gravity.

Since the 1970s, astronomers have known that the outer regions of galaxies appear to violate Newton's gravity laws. We would expect the stars in a galaxy's outer regions to travel in elliptical orbits with their orbital speeds decreasing with increasing distance. However, this is not observed. Instead of decreasing, the speeds are essentially constant over a wide region of the galaxy.

Astronomers hypothesized that the galaxies actually contain large quantities of unseen material that hold the stars in the galaxy. This extra mass — called "dark matter" because it interacts via the gravitational force while remaining impossible to directly observe — brings the dynamics into agreement with Newton.



The Juno mission to Jupiter is expected to launch August 2011. All eyes will be on the Juno spacecraft as it flies by Earth in August 2013 on its way to a 2016 Jupiter arrival. Astronomers believe Juno may also show the mysterious gravity flyby effect. NASA

However, in 1983 Mordehai Milgrom of the Weizmann Institute of Science in Israel first mentioned a different view that a modified Newtonian dynamics (MOND) can explain the observations for all galaxies. This is not a theory, but a modification that simply fits the data.

MOND says that Newtonian dynamics fail in extremely low-density environments. As its name suggests, MOND modifies Newtonian dynamics by making gravity stronger in diffuse systems.

MOND can explain the motions of individual stars in the outer regions of disk galaxies without having to hypothesize matter within the galaxy that is too dark to see. Milgrom proposed that in the outer regions, the laws of motion change — not the laws of gravitation necessarily, but the laws of motion. Closer to the center of the galaxy, and in the solar system, the orbits behave as Newton and Einstein predicted.

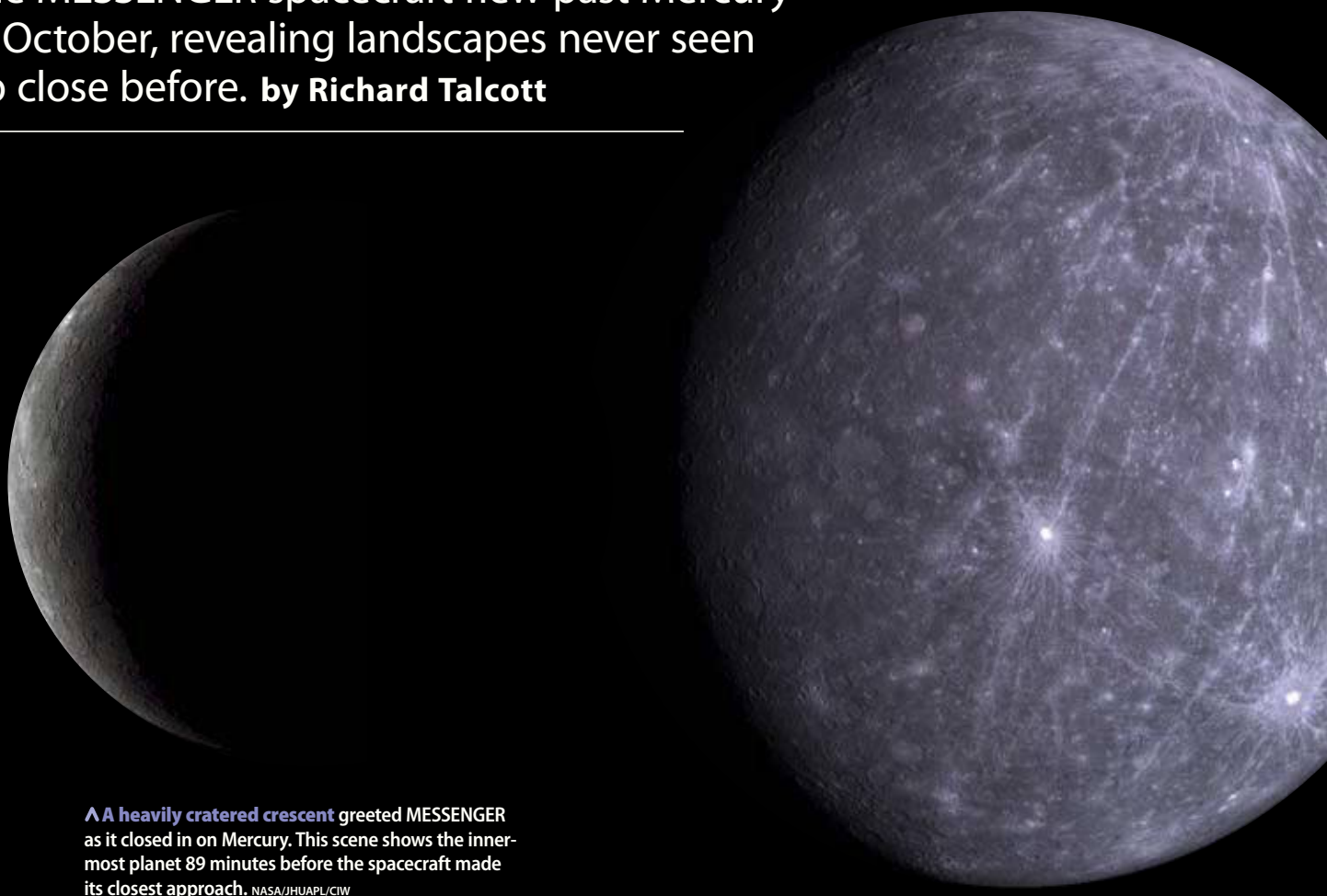
If MOND is indeed the correct alternative to dark matter, a new theory of gravity should eventually explain it. Dark matter should fall out of the theory, so to speak.

We will eventually find what's causing the unexpected shifts and speedups of spacecraft, as well as the apparent changes in the Moon's orbit and the Sun's gravity. Then we may learn that we didn't know as much as we thought about gravity.

Read about what's *not* causing the gravity oddities at www.Astronomy.com/toc.

Surprises from MESSENGER's historic Mercury flyby

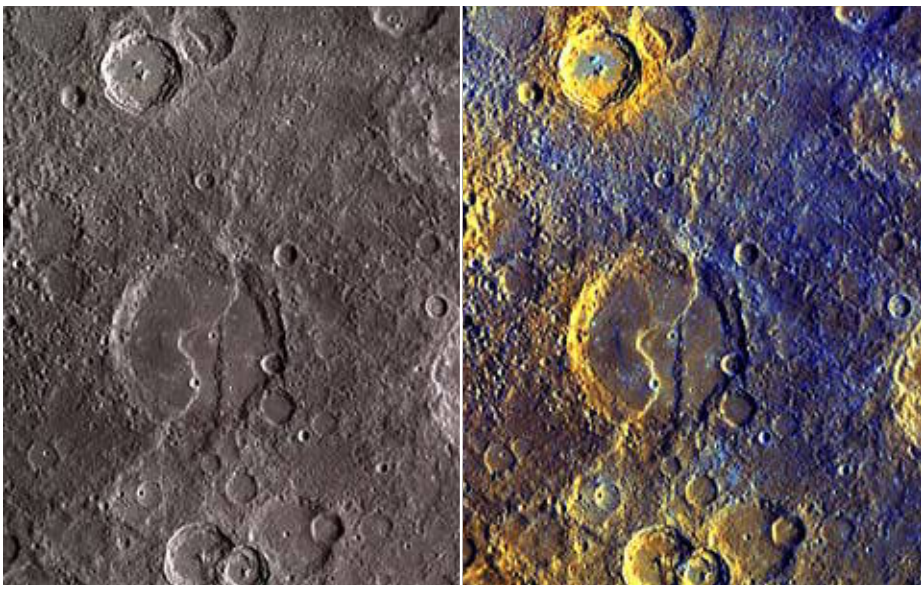
The MESSENGER spacecraft flew past Mercury in October, revealing landscapes never seen up close before. **by Richard Talcott**



∧ A heavily cratered crescent greeted MESSENGER as it closed in on Mercury. This scene shows the innermost planet 89 minutes before the spacecraft made its closest approach. NASA/JHUAPL/CIW

At 4:40 A.M. EDT October 6, NASA's MESSENGER spacecraft skimmed just 123.9 miles (199.4 kilometers) above Mercury's battered surface. The flyby was the craft's second pass by the innermost planet during 2008. The probe's trajectory took it over parts of the planet never viewed in detail before, and scientists took full advantage of the fresh perspective.

MESSENGER — short for MErcury Surface, Space ENvironment, GEochemistry, and Ranging — returned 1,287 images to Earth, as well as observations of the planet's topography, atmosphere, and magnetic field. The spacecraft found no major differences between Mercury's hemispheres, although the surface topography appeared noticeably smoother than during the first flyby. MESSENGER also discovered new constituents in Mercury's atmosphere and a magnetic field nearly aligned with the planet's rotational axis.



Thākur Crater and its neighborhood may look bland in natural color (left), but it explodes with detail in false color (right). MESSENGER scientists created the natural look by combining images taken through blue, green, and red filters. The false-color view combines images taken through 11 filters at visible and near-infrared wavelengths. Such images reveal differences in composition and geological processes. NASA/JHUAPL/ASU/CIW

Viewing the missing pieces

The October flyby marked the fifth time a spacecraft has flown past Mercury. Mariner 10 made the first three encounters during the mid-1970s. Each time, however, the Sun was illuminating the same hemisphere. The result: Mariner 10 imaged only about 45 percent of Mercury's surface.

MESSENGER's January 2008 flyby started to alleviate the shortfall. The craft's cameras captured about 20 percent of the planet that Mariner 10 missed, most of it in the eastern hemisphere. In October, MESSENGER flew over the western hemisphere and imaged roughly 30 percent of Mariner 10's shortfall — an area larger than South America. All told, scientists now have detailed images of more than 90 percent of Mercury's surface, with the largest remaining gaps near the north and south poles.

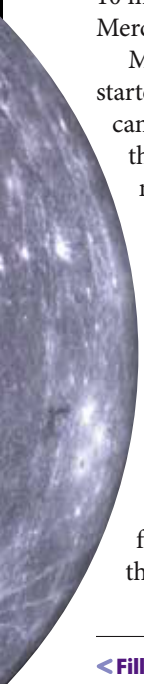
The first thing that stands out from this new global perspective is the absence of major geological differences between the planet's hemispheres. That's unusual in the inner solar system.

"On the Moon, dark volcanic plains are concentrated on the nearside and are nearly absent from the farside," says MESSENGER co-investigator Mark Robinson of Arizona State University. "On Mars, the southern hemisphere consists of older, cratered highlands, whereas the northern hemisphere consists of younger lowlands."

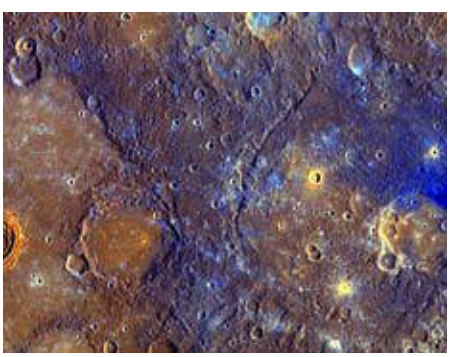
Even on Earth, the Pacific Basin dominates one hemisphere while a mix of continents and oceans inhabit the other. But Mercury appears fairly uniform. It has ancient, heavily cratered terrain interspersed with large expanses of younger volcanic plains.

Despite the homogeneous surface, the subsurface seems significantly more complex. MESSENGER's cameras can take images through 11 filters arrayed across the visible and near-infrared parts of the spectrum. By combining all of these filtered views, scientists create false-color images that highlight differences in composition.

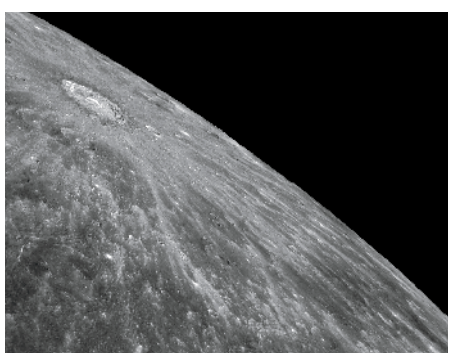
In these images, bright blue ejecta surround many impact craters. These thin deposits are subsurface material excavated by impacts. Yet, in some places, images show one crater surrounded by blue ejecta while a similarly sized neighboring crater is not. This proves that the region below the planet's surface can't be homogeneous. Robinson says Mercury's



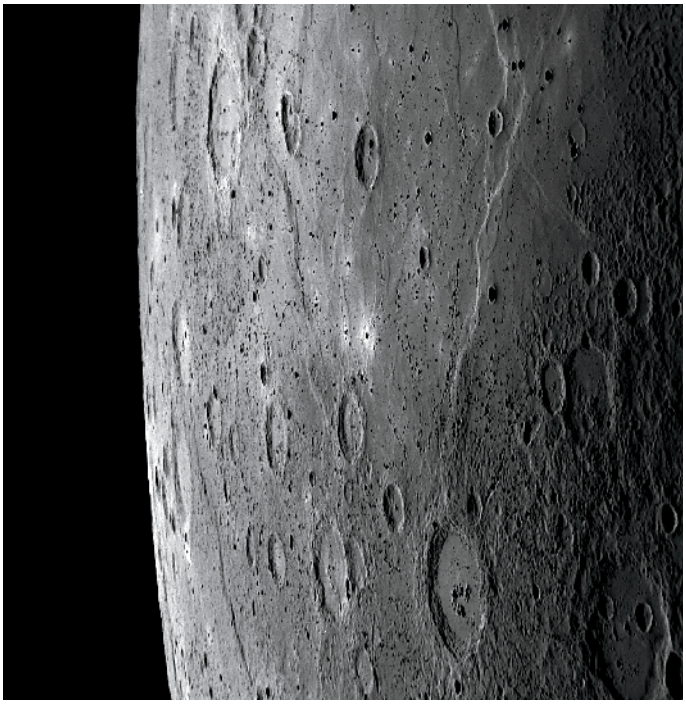
< Filling in the gaps, the MESSENGER spacecraft imaged most of Mercury's previously unseen terrain. The bright crater Kuiper, which Mariner 10 first saw, sits just below center in this view. Most of the territory to Kuiper's east (right) represents virgin land. The subtle coloration approximates what the human eye would see. NASA/JHUAPL/CIW



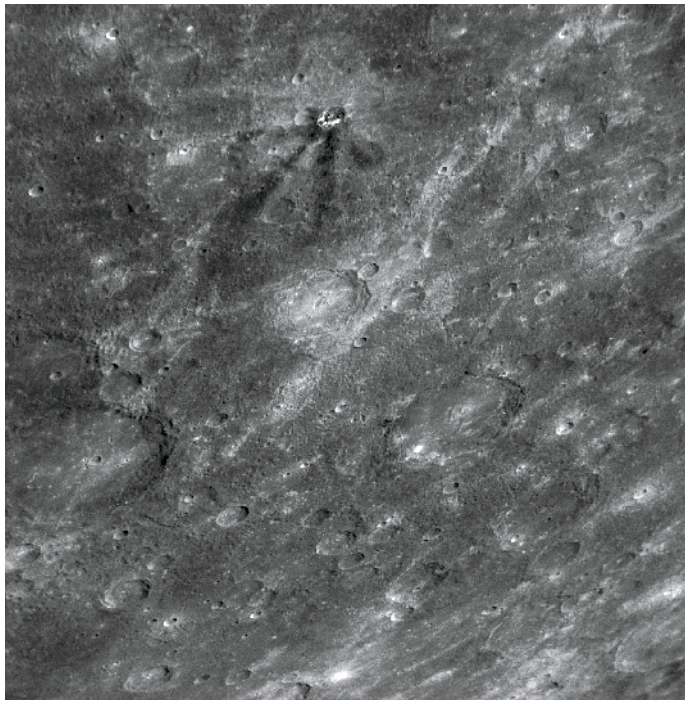
A thin blanket of blue material covers the right side of this false-color image. Impacts dug up this substance from beneath the surface and scattered it across the relatively young, smooth plains (which appear yellow-orange). NASA/JHUAPL/CIW



A spectacular system of bright rays drapes across more than a quarter of Mercury's surface. MESSENGER revealed for the first time the system's extent as well as its source: this young crater near the planet's limb. NASA/JHUAPL/CIW



Smooth plains dominate this part of Mercury's equator. Such terrain appears significantly younger than more heavily cratered regions and probably arose during a period of extensive volcanism. NASA/JHUAPL/CIW



Dark streamers radiate from a crater at the top of this image. Such ejecta usually appear bright as sunlight reflects off freshly pulverized rock. These dark rays may be debris blasted from far beneath the surface. NASA/JHUAPL/CIW

crust more closely resembles a marble cake than a layer cake.

Mercury's highs and lows

The October flyby allowed scientists to tie images to topography for the first time. MESSENGER's laser altimeter measures the height of surface features along a narrow strip. In January, the altimeter observed terrain not yet imaged. But in October, the altimeter revisited ground imaged in January while the cameras photographed regions the altimeter had observed during the previous flyby.

Altimeter observations help scientists interpret surface geology. In one revealing case, the altimeter measured the topographic profile across a pair of side-by-side craters, each 60 miles (100 km) in diameter. The measurements show one crater is some 4 times deeper than the other, implying lava filled its neighbor to a depth of more than 1 mile (2 km).

These and other MESSENGER observations show that Mercury experienced far more volcanic activity than the Moon. Although most of this volcanism occurred early in the planet's history, probably 3.8 to 4 billion years ago, some of it may have persisted much longer.

Richard Talcott *is a senior editor of* Astronomy.

The altimeter track also crossed a wrinkle ridge — a sinuous slope that likely forms when a planet's crust contracts. MESSENGER co-investigator Maria Zuber of the Massachusetts Institute of Technology says the ridge rises nearly 2,000 feet (600 meters) above the surrounding plain. That's twice the relief of the biggest wrinkle ridges on Mars, suggesting Mercury contracted much more than the Red Planet.

Zuber's biggest surprise came from the surface's roughness. The western hemisphere strip seen in October is about 30 percent smoother than the eastern hemisphere strip observed in January. She doesn't know how significant this is — it is just a narrow strip, after all. The spacecraft should reveal the extent of these differences during its orbital mission.

Mercury's odd magnetic field

Just as MESSENGER's trajectory took it over a different part of Mercury's surface, the probe sampled an unexplored part of the planet's magnetic field. The measurements show a highly symmetric magnetic field that tilts no more than 2° from the planet's rotational axis. This makes it more tightly aligned than Earth's 11° tilt.

The spacecraft also sampled Mercury's thin atmosphere. Researchers observed sodium, calcium, and (for the first time) magnesium. Oddly enough, the sodium peaks near Mercury's poles while the calcium concentrates near the equator. Both of these elements originate from Mercury, but their different distributions mean they likely get released in different ways.

One more flyby to go

The main purpose of this flyby, like the previous ones (one of Earth, two of Venus, and the January one of Mercury) was to adjust MESSENGER's speed and course. The spacecraft will fly by Mercury once more, on September 29, 2009, when it will follow a track similar to the October encounter.

This final flyby will set the probe on course to return to Mercury in March 2011, when it will fire its rocket and begin orbiting the planet. For at least 1 Earth year, MESSENGER will loop around the planet in a highly elliptical orbit that will bring it closest to the planet's north pole. It will have been a long journey — 4.9 billion miles (7.9 billion km) and more than 6.5 years — but if the results from the first two flybys are any indication, it will be worth the wait.

To see more results from MESSENGER, visit www.Astronomy.com/toc.

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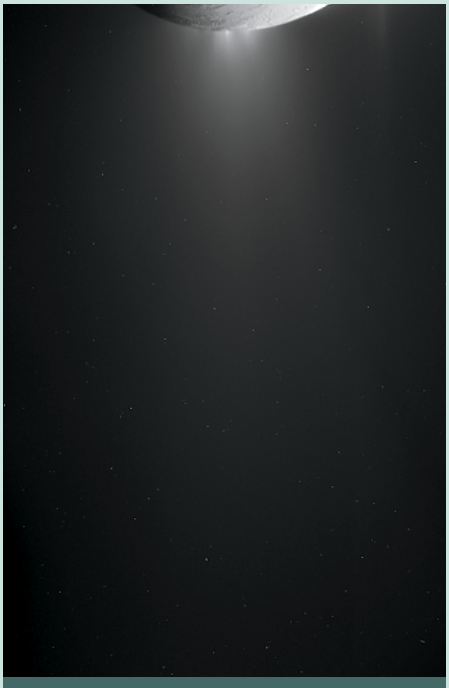
The Cassini spacecraft flew past Saturn's moon Enceladus twice in October, diving into its water-rich plume and imaging its dynamic surface. **by Richard Talcott**

Cassini flies through



Several jets erupt from Enceladus' south pole in this image from September 17. The jets form a vast plume of water vapor and ice that extends hundreds of miles and contributes most of the material to Saturn's E ring and magnetosphere. Cassini snapped this image from a distance of 146,000 miles (235,000 km).

A small, icy moon in the outer solar system might be the last place you'd think to look for geological activity, but Saturn's moon Enceladus is full of surprises. In 2005, NASA's Cassini spacecraft discovered a plume of water vapor and water ice erupting from the moon's south polar region. This finding makes Enceladus a top priority during Cassini's extended Equinox Mission, which started in July after the spacecraft's initial 4-year mission concluded.

October provided planetary scientists with two close looks at Enceladus. On October 9, Cassini skimmed within 16 miles (25 kilometers) of the moon's surface. This marked the spacecraft's closest approach to any saturnian moon. The goal: fly through dense regions of the geysers and analyze their constituents.

Cassini's fields and particles instruments took center stage during this encounter, while the cameras remained on the sidelines at closest approach. Preliminary results show the plume and the powerful jets that create it to be rich in water vapor, ice, and organic compounds.

Just 3 weeks later, on October 31, Cassini returned to Enceladus. This time the craft approached within 108 miles (174 km) of the surface. The greater distance gave the cameras an opportunity to view Enceladus' south pole and the "tiger stripe" fractures where the geysers originate. During both October flybys, Cassini approached Enceladus from north of the moon and exited over the sunlit south pole, mimicking the previous August 11 encounter.

Richard Talcott *is a senior editor of* Astronomy.

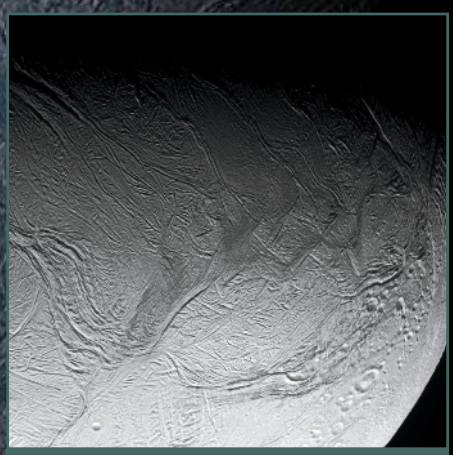
Skeet shooting on Enceladus

Zipping past the moon at 40,000 mph (64,000 km/h), Cassini's cameras couldn't just point and shoot. "Enceladus was streaking across the sky so quickly that the spacecraft had no hope of tracking any feature on its surface," says imaging team member Paul Helfenstein of Cornell University. Helfenstein developed the innovative "skeet shooting" technique Cassini scientists used to get their high-resolution pictures. To compensate for the motion, the imaging team pointed the spacecraft far ahead of Enceladus, then spun the spacecraft and camera as fast as possible to track the moon's motion.

The images show that the four main tiger stripes — Alexandria Sulcus, Cairo Sulcus, Baghdad Sulcus, and Damascus Sulcus — extend some 980 feet (300 meters) deep and have V-shaped inner walls. (Like all features on Enceladus, the stripes are named for people and places that appear in Richard Burton's translation of *The Arabian Nights*. A sulcus is a ridge or furrow.) Blocks of ice the size of small houses litter the terrain surrounding the fractures, and fine material covers the outer flanks of several of them.

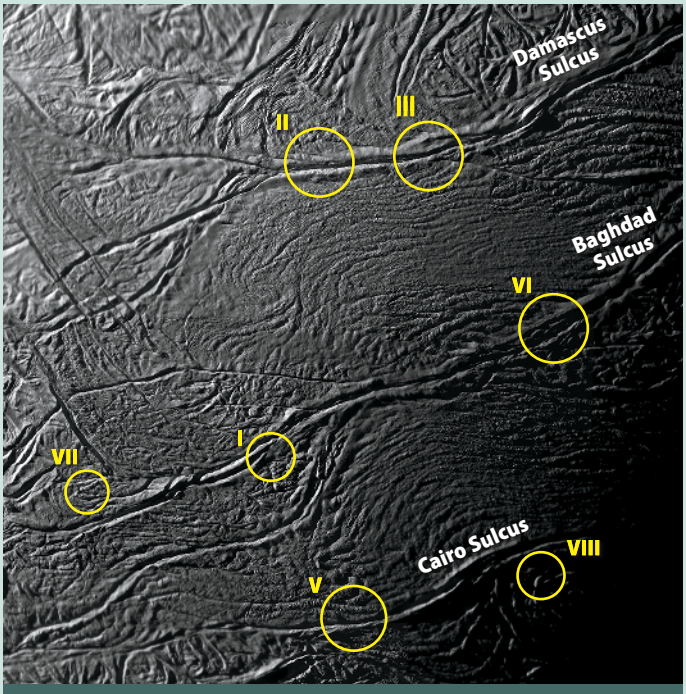
The tiger stripes appear to be similar to the mid-ocean ridges on Earth's seafloors. "Enceladus has earthlike spreading of its icy crust, but with an exotic

Enceladus' geysers

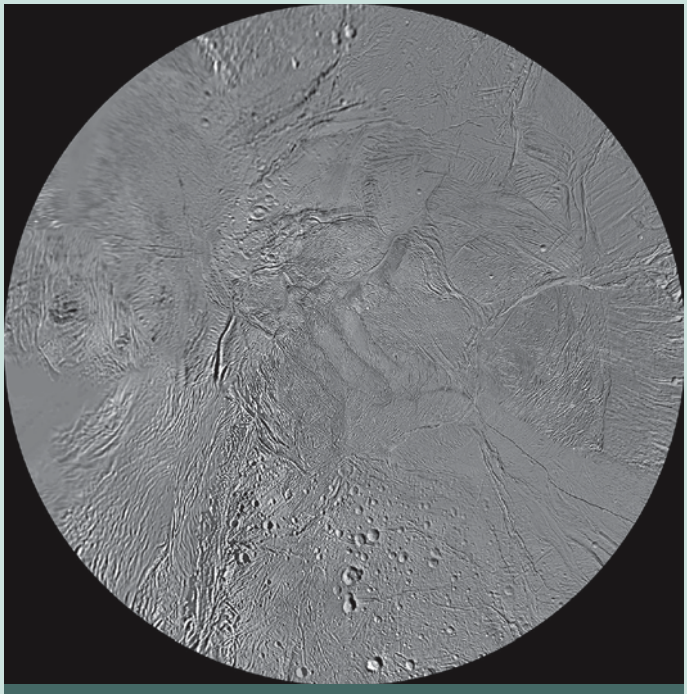


Cassini dove through Enceladus' plume October 9. Although scientists turned off the spacecraft's cameras at closest approach (16 miles [25 km]), they took a few images from farther out. This one shows fractures from 29,000 miles (47,000 km) away.

The tiger stripe terrain on Enceladus stands out near the bottom of this false-color mosaic created from Cassini images taken October 9. In this view, greenish areas correspond to coarse-grained ice and small boulders, which concentrate along valley walls and floors as well as the upraised flanks of the stripes. Whitish areas represent deposits of water ice with finer grains. All images: NASA/JPL/SSI



Nearly parallel gouges known as tiger stripes cross the moon's south polar region. Scientists have identified the sources of eight jets, seven of which appear in this mosaic, along these stripes. The sources, designated by Roman numerals, lie within the circles.



Enceladus' entire southern hemisphere appears in this mosaic, which combines photos from Cassini flybys in March, August, and October 2008. Details as small as 0.6 mile (1 km) across show up in the mosaic's highest-resolution sections.

difference — the spreading is almost all in one direction," says Helfenstein. The scientist likens the spreading to a conveyor belt.

During the August and late-October flybys, Cassini took high-resolution photographs of six of the eight known jet sources. The photos bolster the imaging team's idea that condensation from the erupting jets creates ice plugs in the surface. These plugs close off old vents and cause new ones to open.

The geysers spew prodigious amounts of material into the space surrounding Enceladus. "We know that Enceladus produces a few hundred kilograms [several hundred pounds] per second of gas and dust and that this material is mainly water vapor and water ice," says Cassini scientist Tamas Gambosi of the University of Michigan.

The plume extends more than 300 miles (500 km) above the surface — a height roughly equal to the moon's diameter — and Enceladus' weak gravity can't hold onto it. This material contributes most of the mass found in Saturn's extensive magnetosphere as well as the bulk of the planet's giant but tenuous E ring. One of the biggest puzzles scientists now face is trying to understand how the gas gets ionized and moves throughout the planet's vast magnetosphere.

Liquid water below the surface?

Perhaps an even bigger question: What generates the geysers? Many scientists think liquid water — perhaps even an ocean — lurks beneath the moon's frozen surface. If so, it likely resides closer to Enceladus' surface than the underground ocean does on Jupiter's moon Europa.

But other researchers have their doubts. One model suggests the jets arise when Saturn's tidal forces open vents inside the tiger stripes. Volatile ices then get exposed to space and violently erupt from the surface. If true, the jets should be strongest when Enceladus lies near Saturn and tidal forces peak, and then weaken or shut down when the moon ventures far from Saturn.

A team of planetary scientists has thrown cold water on this idea. The researchers measured the density of the plume in 2005 and 2007 and found the opposite relation. Team leader Candace Hansen of NASA's Jet Propulsion Laboratory says that the new findings, reported in the November 27 issue of *Nature*, support a model that views the vents as nozzles that channel water vapor from a warm and probably liquid source to Enceladus' surface at supersonic speeds.

Where does Enceladus get the energy for this activity? Its short supply of radioactive elements can't produce significant internal heat, and its current orbital configuration doesn't generate much tidal heating. At the moment, the mechanism behind Enceladus' heat remains as much of a mystery as the geysers themselves.

As darkness descends

Although Cassini will return to Enceladus' vicinity several more times during the Equinox Mission, the October flybys likely were our last good look at the geyser region. By the time of the next close encounter in November, the Sun will have set on the moon's south pole.

Saturn and its moons reach their spring equinoxes in 2009. This means the Sun will illuminate less of the tiger stripe terrain during the next several years and what remains on view to Cassini will grow dimmer. Fortunately for scientists, the observations on hand should keep them busy for years to come.

To see more results from Cassini's most recent flybys of Enceladus, visit www.Astronomy.com/toc.

NEXT MONTH
in the April issue

NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Astronomy
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Why the universe has no beginning
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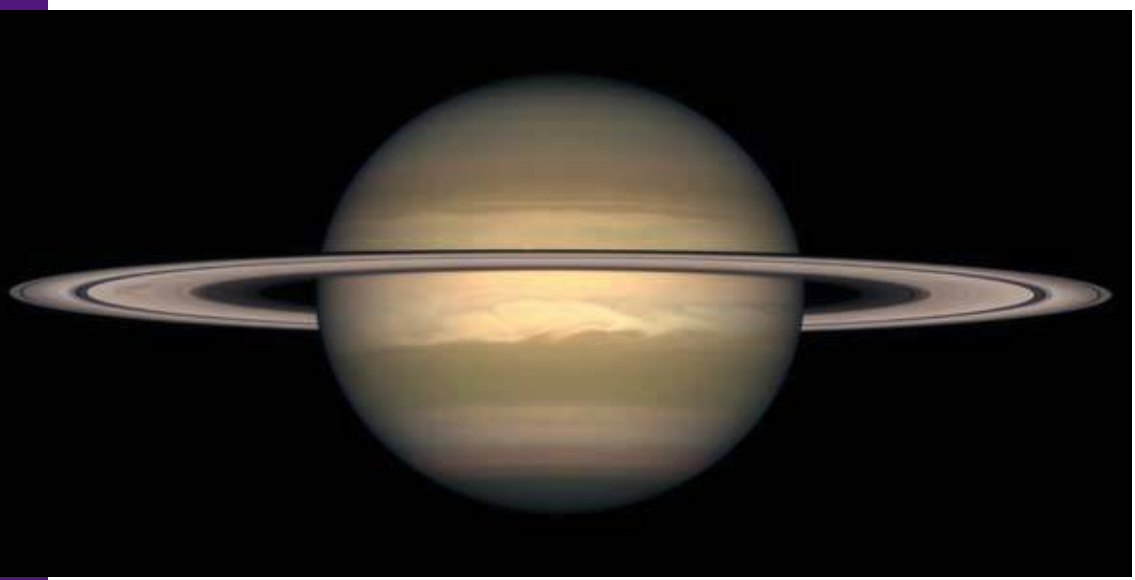
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

March 09

Saturn returns to glory

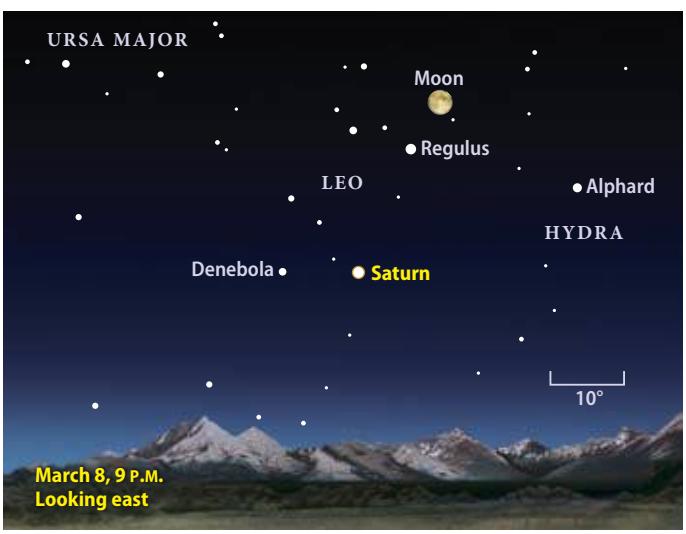


Saturn's rings appear thin in March as we approach this summer's ring-plane crossing. Hubble snapped this image in October 1996 when the rings had a similar tilt. NASA/ESA/Hubble Heritage Team (STScI/AURA)

36 Saturn reigns all night
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 View Saturn's moons
42 Comet search
43 Locating asteroids
43 Farewell evening star

Visible to the naked eye
Visible with binoculars
Visible with a telescope

This month brings a dramatic end to Venus' long evening apparition. The brilliant planet's changing position relative to the Sun causes it to nose-dive into the evening twilight. The shifting geometry also generates stunning changes in how Venus appears through any telescope.



Saturn reaches the peak of its 2009 apparition this month when it lies opposite the Sun in our sky and remains visible all night. *Astronomy*: Roen Kelly

You'll find Saturn in the opposite part of the early evening sky. The ringed planet reaches opposition and peak visibility March 8. Nearby lies the brightest dwarf planet, Ceres, putting on one of its best shows in years. By the time Saturn and Ceres dip low in the west before dawn, Jupiter crawls out of the solar glare. Sharp-eyed observers may even spot Mercury and Mars low in morning twilight.

You'll want to begin your planet viewing shortly after sunset. Dazzling **Venus** dominates the evening sky in early March. On the 1st, it lies 35° east of the Sun and sets 3 hours after sunset. A smiling crescent Moon stands high above the planet. Through a telescope, Venus appears 19 percent lit, slightly thinner than the lunar crescent.

But Venus' reign as the evening star won't last the month. Each consecutive day, the planet lies lower in the sky. The gap between sunset and Venus-set drops from 3 hours March 1 to 2 hours March 10 and to just 1 hour March 20. Venus passes nearly between the Sun and Earth at inferior conjunction March 27.

As Venus moves toward inferior conjunction, it comes closer to Earth and its lit hemisphere turns away. The view through a telescope reflects these changes: Venus' disk grows larger while its phase dwindles. On March 1, the planet appears 45" across and 19 percent lit. By the 10th,

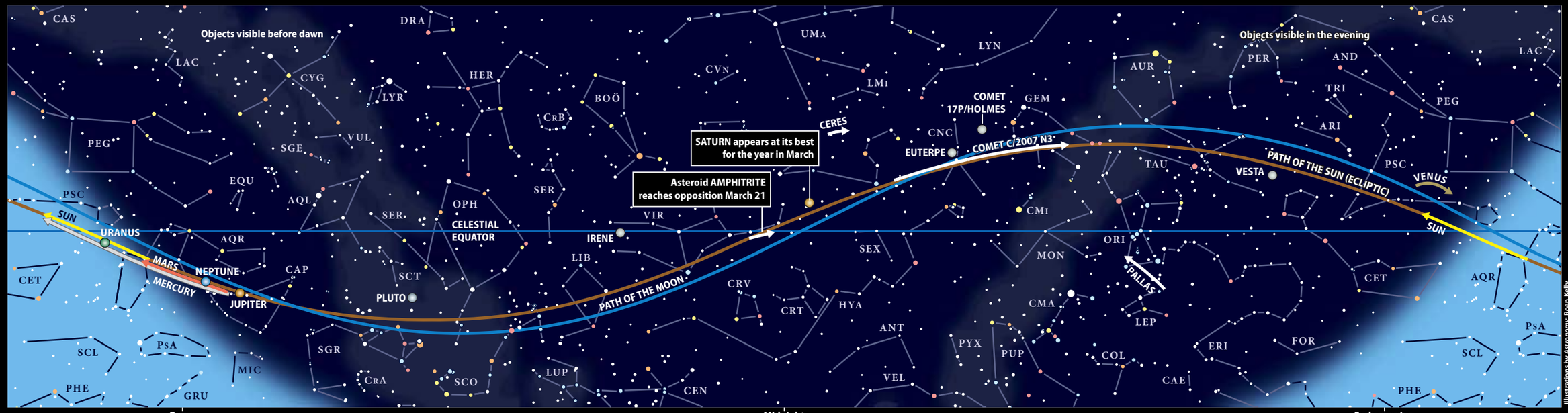
— *Continued on page 41*

Planets in March 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets

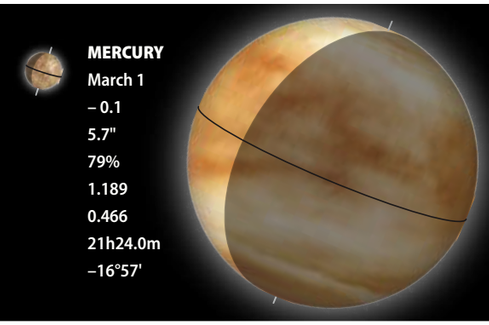


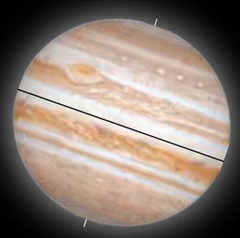
Illustrations by *Astronomy*: Roen Kelly

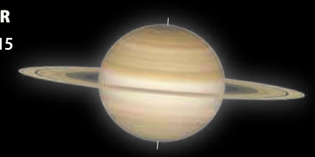
MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	March 1	March 1	March 15	March 15	March 15	March 15	March 15	March 15	March 15
Magnitude	– 0.1	– 4.8	1.2	7.1	–2.0	0.5	5.9	8.0	14.0
Angular size	5.7"	45.1"	4.2"	0.8"	33.8"	19.8"	3.3"	2.2"	0.1"
Illumination	79%	19%	98%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.189	0.370	2.232	1.621	5.825	8.401	21.093	30.894	31.747
Distance (AU) from Sun	0.466	0.719	1.391	2.549	5.089	9.388	20.099	30.032	31.613
Right ascension (2000.0)	21h24.0m	0h44.5m	22h09.1m	10h46.6m	21h12.8m	11h18.5m	23h33.9m	21h49.4m	18h12.8m
Declination (2000.0)	–16°57'	11°23'	–12°38'	25°44'	–16°41'	6°56'	–3°37'	–13°33'	–17°41'

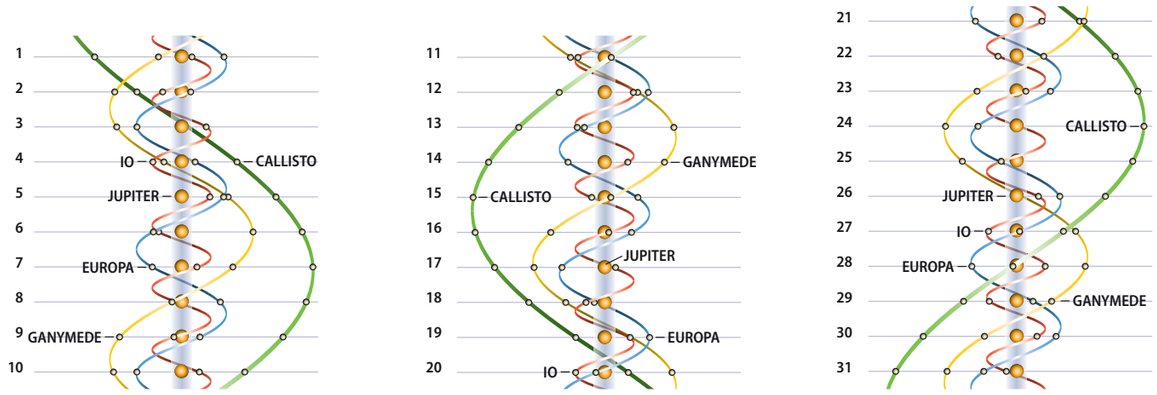






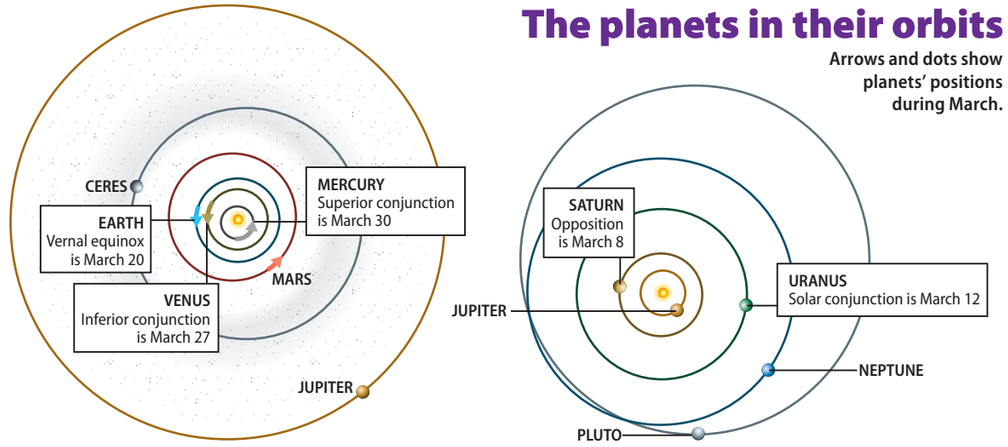
Jupiter's moons

Dots display positions of Galilean satellites at 7 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during March.



StarDome

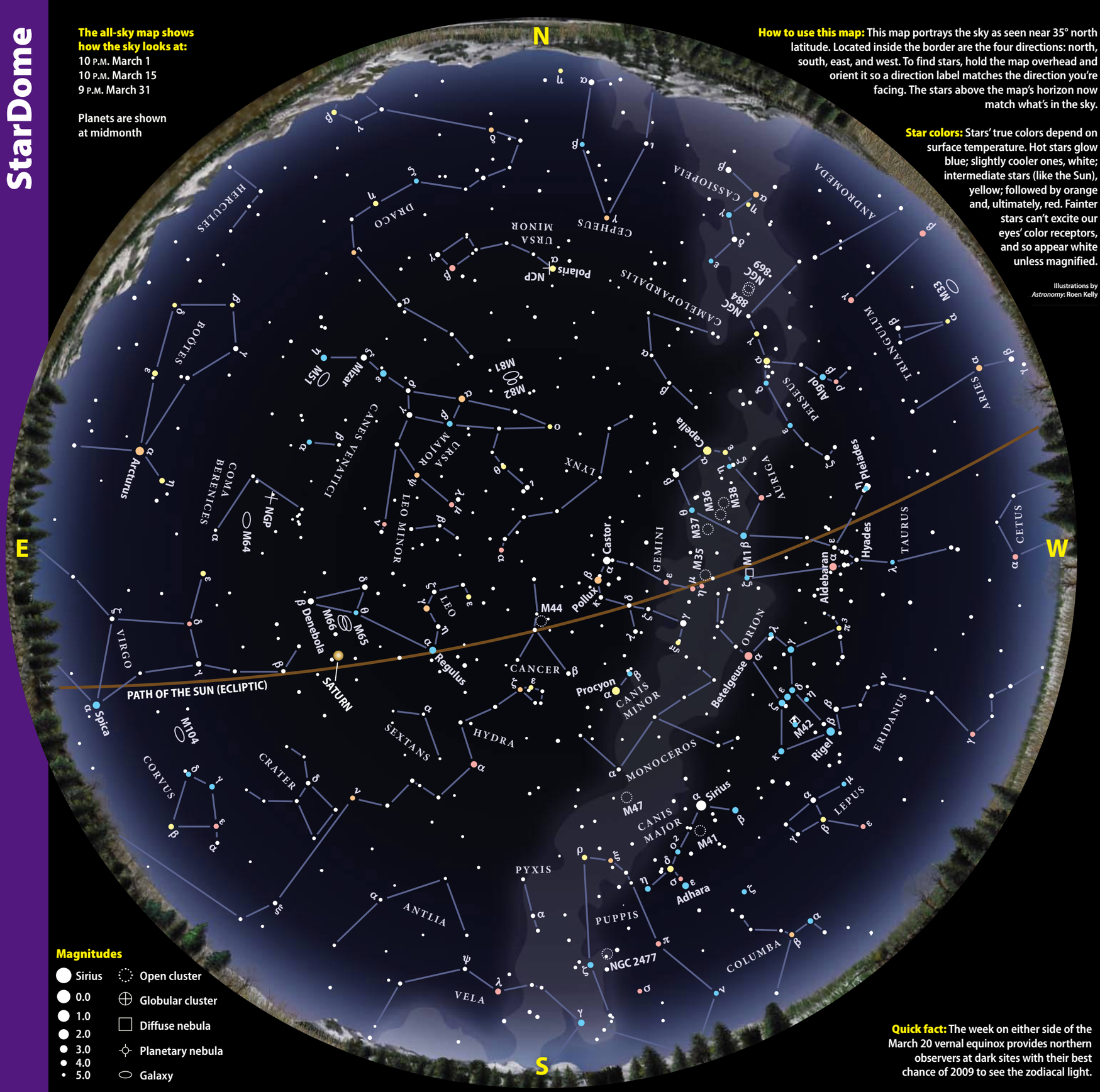
The all-sky map shows how the sky looks at:
10 P.M. March 1
10 P.M. March 15
9 P.M. March 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: The week on either side of the March 20 vernal equinox provides northern observers at dark sites with their best chance of 2009 to see the zodiacal light.

March 09

Note: Moon phases in the calendar vary in size due to distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Calendar of events

1 Mercury passes 0.6° south of Mars, 3 P.M. EST

4 First Quarter Moon occurs at 2:46 A.M. EST

7 The Moon is at perigee (228,054 miles from Earth), 10:07 A.M. EST

Mars passes 0.8° south of Neptune, 11 P.M. EST

8 Saturn is at opposition, 4 P.M. EDT

Special observing date

8 Saturn shines brighter and appears larger than at any other time this year.

10 F
10:38 P.M. EDT

The Moon passes 6° south of Saturn, 11 P.M. EDT

12 Uranus is in conjunction with the Sun, 9 P.M. EDT

17 The Moon passes 0.2° north of Antares, 1 A.M. EDT

18 Last Quarter Moon occurs at 1:47 P.M. EDT

19 The Moon is at apogee (251,220 miles from Earth), 9:15 A.M. EDT

20 Vernal equinox occurs at 7:44 A.M. EDT

21 Asteroid Amphitrite is at opposition, 2 P.M. EDT

22 The Moon passes 1.5° north of Jupiter, 5 P.M. EDT

23 The Moon passes 2° north of Neptune, 10 A.M. EDT

24 The Moon passes 4° north of Mars, 10 A.M. EDT

26 N
at 12:06 P.M. EDT

27 Venus is in inferior conjunction, 3 P.M. EDT

30 Mercury is in superior conjunction, 11 P.M. EDT

For definitions of terms, log onto www.Astronomy.com/glossary.

Astronomy magazine

— *Continued from page 36*

Venus' disk spans 52" and shows an 11 percent phase. And on March 20, a telescope reveals a 58"-diameter disk that's 3 percent illuminated. The diminishing crescent causes Venus to dim from magnitude –4.8 to –4.3 between the 1st and the 20th.

When Venus reaches inferior conjunction, it passes nearly 10° north of the Sun. This abnormally large angular separation brings Venus back into view within days, but now in the morning sky. Venus rises 50 minutes before the Sun March 31, when it's a challenging object in bright twilight. Still, at magnitude –4.2, you might be able to glimpse it. Through a telescope, Venus then appears 59" across and just 1 percent lit.

A telescope can reveal many wondrous sights throughout the cosmos. Yet most observers would agree that none of these vistas matches the beauty of **Saturn**. You can judge for yourself as the ringed planet reaches its 2009 peak this month.

Saturn lies opposite the Sun in our sky March 8, which keeps it visible all night. Opposition also brings Saturn closest to Earth, so it shines brightest and appears biggest through a telescope. Saturn peaks at magnitude 0.5, making it the brightest object in its host constellation, Leo the Lion. The planet lies in southern Leo, beneath the Lion's hindquarters.

To see Saturn at its best through a telescope, wait until it climbs at least one-third of the way to the zenith. Once the planet reaches this altitude (30°), its light passes through far less of Earth's atmosphere, improving the chances for steady views. On March 1, Saturn stands 30° above the horizon by 9 P.M. local time. By month's close, it's already this high when twilight ends.

Even at a distance of 780 million miles, Saturn looks

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada in Edmonton, Alberta.*

Meteor watch

The zodiacal light glows nicely once evening twilight ends after mid-March. You need a dark sky to see the light. Rob Ratkowski

Dust sets the zodiac aglow

Meteor activity remains low during March. The only shower is a minor one deep in the southern sky. Still, you might see fine meteor dust in the form of the zodiacal light. This faint glow shows up best from dark observing sites during the moonless evenings after mid-March. Well after the Sun sets, twilight's last gleaming will give way to a lingering cone-shaped glow — the zodiacal light. The glow extends up through Aries and into Taurus.

The zodiacal light represents sunlight reflecting off dust particles concentrated along the ecliptic, the plane of our solar system. Because the dust lies in the ecliptic plane, the glow follows the constellations of the zodiac (hence the name). The glow shows up best when the ecliptic makes a steep angle to the horizon. In the Northern Hemisphere, this happens on evenings in early spring.

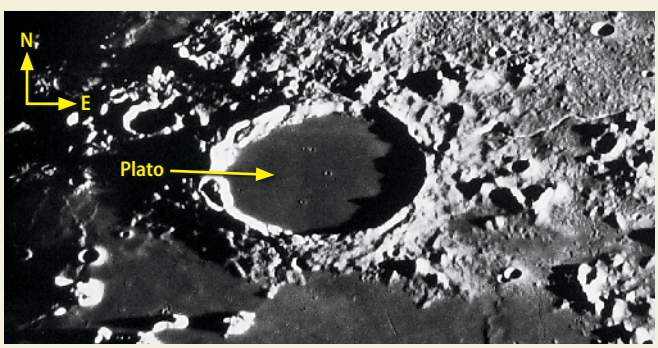
Rising Moon

Contemplating a conspicuous crater

Shortly after the Sun sets March 4, Moon watchers will see an oval of darkness surrounded by a bright rim. This is Plato, a sharp-walled crater in the Moon's northern hemisphere. As the Sun climbs higher in the lunar sky later in the evening, the crater's floor catches more sunlight and long jagged shadows begin their retreat. After watching these changes, you'll see why Plato impresses newcomers as much as it mesmerizes experienced selenophiles.

Like all major lunar craters, the impact that gave birth to Plato created a central peak. But you won't see any central peak when you look at Plato. It lies buried beneath the smooth pond of lava that welled up through cracks in the floor during the great lava floods some 3.5 billion years ago. Since then, a handful of much smaller impacts have pockmarked Plato's frozen floor. With a steady atmosphere to look through, patient observers with a 6-inch telescope can pick out the largest of the craterlets near Plato's center.

As the Sun climbs higher in Plato's sky during the next several evenings, return to the crater and take a close look at the way the walls slumped into the basin. You can replicate some of these features the next time you go to the beach. Simply dig to different depths in moist sand and watch how the sides cave in. Also compare the texture just inside and outside the crater's rim. Although you may not be able to resolve the tiniest features, the smooth floor appears noticeably different from the dappled area beyond the elevated rim.

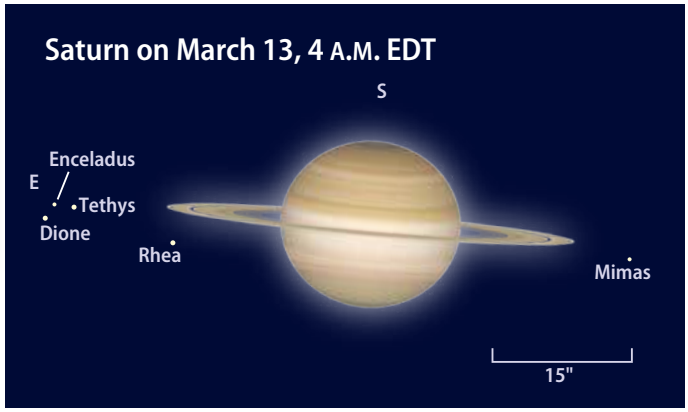


The oval crater Plato stands out in the Moon's northern hemisphere. The 63-mile-wide crater features sharp walls and a dark floor pocked with a few craterlets. *Consolidated Lunar Atlas*/UA/LPL

As a bonus the evening of March 4, look along the terminator a bit south of the Moon's equator. There you'll see the Straight Wall casting a long, sharp shadow.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (west)	Saturn (south)	Mercury (southeast)
Saturn (east)		Mars (east)
		Jupiter (southeast)
		Saturn (west)



Astronomy: Roen Kelly

Four saturnian moons cluster together before dawn March 13. Watch Tethys, Dione, Enceladus, and Rhea change positions in as little as 10 minutes.

spectacular. All month long, its disk spans 20", and the rings extend 45". The rings currently tilt 3° to our line of sight, so they cut a narrow swath across Saturn's disk. Seeing the rings in front of the disk won't be easy, but look for their fine black shadow under good conditions. The lit part of the rings show up best against the dark backdrop off the planet's disk.

The ring system's tilt increases nearly 50 percent during March, from 2.3° to 3.4°. The tilt will continue to grow until May, when it reaches 4.2°, before it starts to narrow again. The rings will appear edge-on in September. Unfortunately, Saturn won't be visible then because it will lie near the Sun in our sky.

The narrow ring-tilt provides observers with a good view of Saturn's disk. Look for subtle shading, particularly in the darker polar regions. You also may notice the north and south equatorial belts, which appear slightly darker than their surroundings.

Most of Saturn's major moons orbit in nearly the same plane as the rings. The current low ring-tilt means the moons now appear to line up better than they usually do. Most of the large moons also pass in front of Saturn once each orbit. Titan, Saturn's biggest and brightest moon, casts a dark shadow onto Saturn's disk when the moon crosses between the Sun and Saturn. Two of these rare shadow transits occur in March.

The first comes before dawn March 12. Titan's shadow appears on Saturn's globe starting at 5:34 A.M. EDT (2:34 A.M. PDT). It will take a few minutes for the shadow to become noticeable because it falls in Saturn's north polar region. At the same time, Titan will show up easily just off the planet's eastern limb. It glows at magnitude 8.2. Although observers throughout North America will see the shadow transit begin, only those in the western half will see it end. The shadow leaves Saturn's disk at 5:51 A.M. PDT.

The second event occurs before dawn March 28. And, once again, all North Americans with clear skies can see the first part of the shadow transit, while only those out west can see it conclude. The shadow enters Saturn's north polar region at 4:25 A.M. EDT (1:25 A.M. PDT) and leaves the disk at 5:23 A.M. PDT.

Of Saturn's other moons, Rhea glows brightest, at magnitude 9.5. It's easy to spot throughout most of its 4.5-day orbit. Tethys (magnitude 10.0) and Dione (magnitude 10.2) also show up in most scopes. The narrow rings don't reflect as much light in our direction as usual, which enhances the moons' visibilities.

The inner moon Enceladus proves harder to see. It glows at magnitude 11.5, so you'll need a 6-inch telescope to see

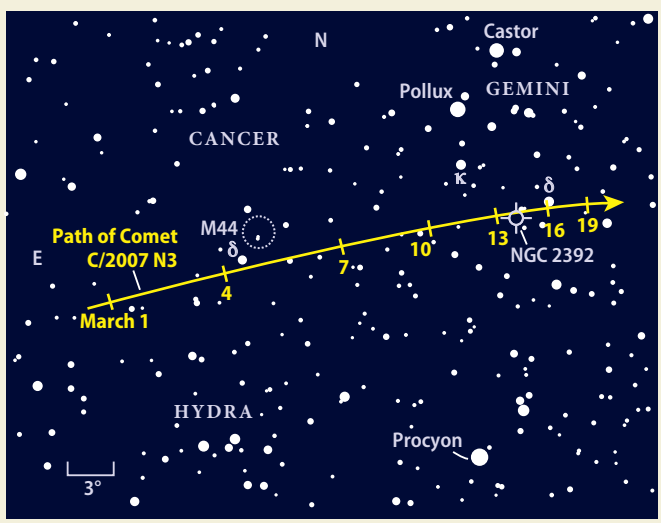
Comet search

Catch the last of Lulin

The show is almost over for winter's delightful Comet C/2007 N3 (Lulin). Well placed in the southeast during the evening in early March, Lulin should glow around 7th magnitude. That would bring it within range of binoculars from the suburbs. However, this age-old ball of ice and dust is looping through the solar system in the direction opposite Earth's motion, so our separation increases rapidly. The comet should dim to 9th magnitude by month's end.

A nice photo opportunity presents itself March 5, when Lulin passes 2° south of the large, bright star cluster known as the Beehive (M44) in Cancer. To maximize the length of the comet's tail in your images, plan to shoot around 3 A.M. local time. This gives the waxing gibbous Moon time to set.

Comet Lulin has a second nice conjunction March 14. That evening, the comet passes just 15' (half the Moon's apparent size) from the Eskimo Nebula (NGC 2392). The Eskimo is a classic planetary nebula: a small round disk with a bright central star. The stark difference between the comet and nebula likely will show up best to visual observers. The nebula's small size relative to its distance from the comet will challenge imagers to capture a balanced view.



Comet C/2007 N3 (Lulin) glows at 7th magnitude early this month. It passes the Beehive star cluster (M44) March 5 and the Eskimo Nebula (NGC 2392) March 14. *Astronomy*: Roen Kelly

Locating **asteroids**

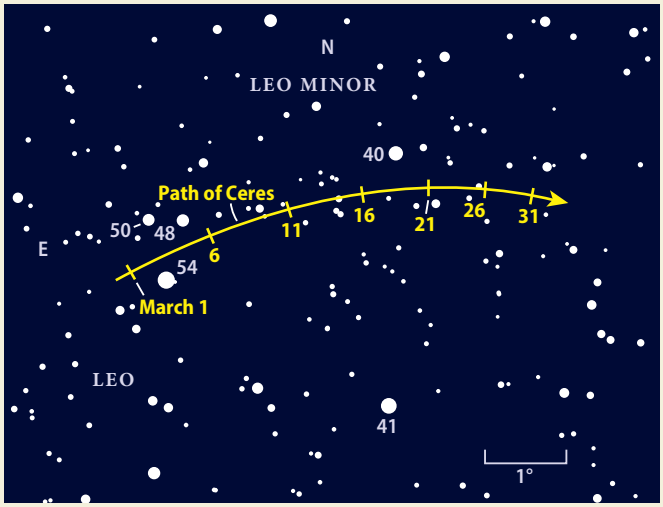
Trapped between two lions

Asteroid 1 Ceres escapes the clutches of Leo the Lion this month, but it may not fare much better in Leo's smaller cousin, Leo Minor. Ceres treads carefully in the open spaces of southern Leo Minor. Only a handful of stars in this area glow brighter than the 7th-magnitude asteroid. You shouldn't have much trouble tracking the starlike dot with binoculars, even from a suburban observing site.

Your signpost to Ceres is the 4th-magnitude star 54 Leonis. To find this star, use the StarDome at the center of the magazine. Scan from Denebola (Beta [β] Leo) through Delta (δ) Leo to the next bright star one binocular field away. That's 54 Leo.

Turn a telescope to 54 Leo, and you'll find it's a nice double star. The primary shines at magnitude 4.5 and the secondary at magnitude 6.3. A modest 6" separate the two. Bump the magnification past 125x to get a good look.

Ceres made its closest approach to Earth February 25. It won't be this close again until the year 3000 at least, and probably not for many millennia afterward. Slight gravitational tugs from the planets conspire to make Ceres' orbit more circular during the coming centuries, preventing Ceres from dipping as close to Earth.



Asteroid Ceres plies the Lion's den in March, not far from the 4th-magnitude star 54 Leonis. The 7th-magnitude space rock shows up nicely through binoculars. *Astronomy*: Roen Kelly

it. Yet it's worth seeking simply because it's one of the solar system's most active moons. The orbiting Cassini spacecraft discovered geysers near the moon's south pole. Scientists speculate that an ocean of liquid water lies beneath the moon's surface of water ice.

Occasionally, several moons will cluster together on one side of the planet. If you look before dawn March 13, you'll see Dione, Enceladus, and Tethys next to one another, with Rhea even closer to Saturn's limb. You can see changes in their relative positions within minutes.

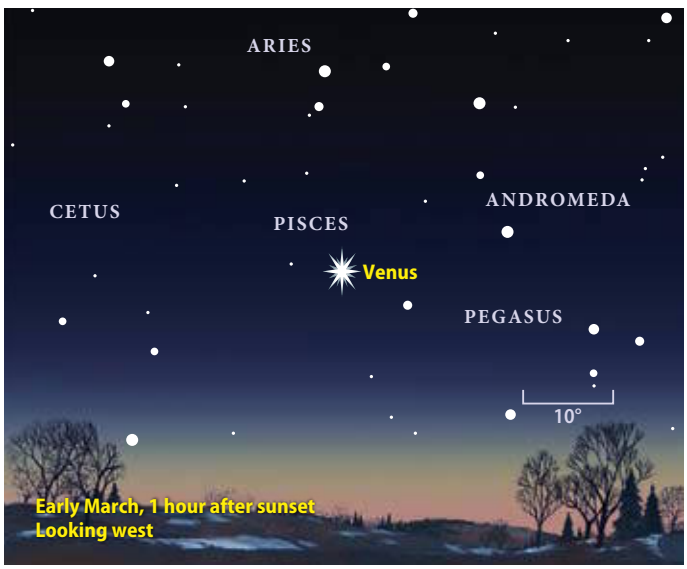
The outermost major moon, Iapetus, shows up best in late March. It passes south of Saturn March 15 and brightens as it moves west of the planet. Greatest western elongation arrives April 2, when Iapetus peaks at magnitude 10.1. It appears less than half that bright when it lies south of Saturn. See if you can detect the brightness change during March's final 2 weeks.

The dwarf planet **Ceres** reached opposition in late February and begins March glowing at magnitude 6.9. This appearance merits special attention because Ceres hasn't come closer to Earth since 1857. It won't be as near again for at least 1,000 years.

Ceres glows just below naked-eye visibility and shows up easily through binoculars. It lies less than 1° from the 4th-magnitude star 54 Leonis throughout the first week of March. To locate and track Ceres this month, use the finder chart at the top right of this page.

Jupiter remains in morning twilight throughout most of March, climbing slowly higher as the month progresses. Still, it appears conspicuous because it shines so brightly, at magnitude –2.0. For a superb predawn sight, look for Jupiter 4° to the lower left of a slim crescent Moon the morning of March 22.

Two mornings later, an even-thinner Moon stands 3° to the upper left of **Mars**. You'll be hard-pressed to see Mars without optical aid. The Red Planet shines at magnitude 1.2 and lies just 4° high



Venus rules the evening sky in early March but quickly descends into the twilight glow. The brilliant planet appears as a large, thin crescent through a telescope. *Astronomy*: Roen Kelly

30 minutes before sunrise. Binoculars will help you spot it. Mars creeps higher in the sky each consecutive morning, but even so, it manages to rise only about an hour before the Sun by March 31. Better views of Mars await patient observers toward the end of the year.

Mars lies less than 1° from **Mercury** before dawn March 1. You'll need a clear and unobstructed horizon to see the pair because the two reach an altitude of just 3° half an hour before sunrise. Mercury shines at magnitude –0.1, noticeably brighter than Mars. Brilliant Jupiter can serve as a guide. Once you find this bright planet, scan with binoculars 6° to the lower left to reach the fainter pair. Within just a few days, Mercury disappears into bright twilight.

How the Spitzer Space Telescope unveils the unseen cosmos

NASA's flagship infrared eye in the sky has probed hidden corners of the universe for 5 years. Spitzer chief scientist Michael Werner shares some of the telescope's greatest discoveries.

A hidden universe exists in parallel with the one you can observe through a telescope eyepiece. It is the infrared sky, radiating energy at wavelengths just beyond the reddest light visible to the unaided eye. Since its launch in August 2003, NASA's Spitzer Space Telescope has explored the infrared universe with unprecedented sensitivity and image sharpness.

Using Spitzer, astronomers can see relatively "cool" targets like planets in other star systems, which don't emit enough light to be visible in other wavelengths. The telescope has peered through the dense interstellar dust that veils much of our own Milky Way Galaxy, exposing previously unseen structures. Researchers also use the observatory to zero in on massive black holes in the cores of dust-obscured galaxies.

Spitzer's farthest frontier is the early universe, the period when the first stars and galaxies formed. Their light departed in the visible and ultraviolet spectrum, but the expansion of space stretched it into the infrared on its way to us. Spitzer's instruments detect this ancient light, enabling astronomers to study galaxies whose light left them 12.8 billion years ago, when the universe was one-seventh its present size.

Michael Werner *has been the project scientist for the Spitzer Space Telescope since 1984. He is also the chief scientist for astronomy and physics at the NASA/Caltech Jet Propulsion Laboratory in Pasadena, California.*

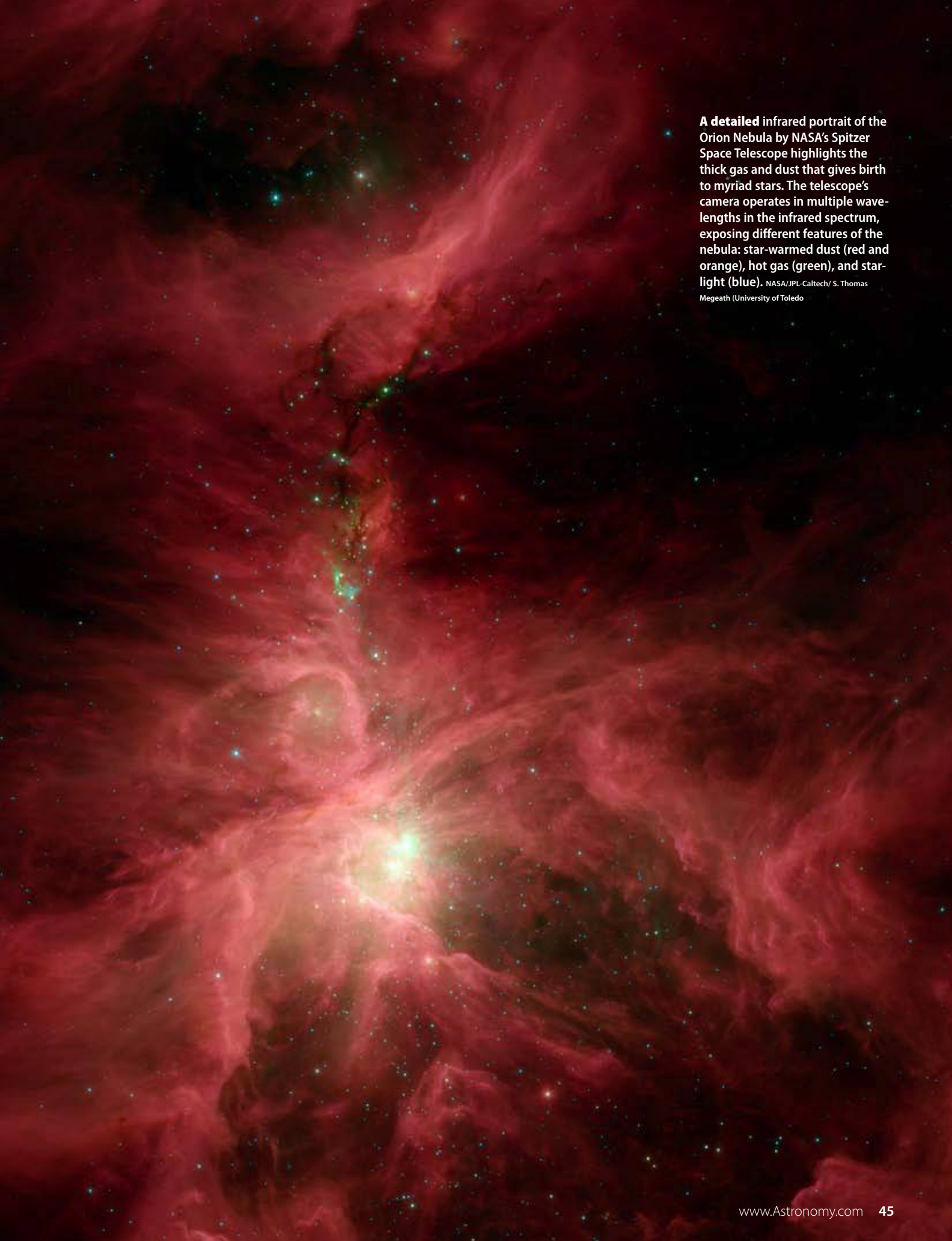
Spitzer's mission is now in its sixth year. The wide-ranging discoveries credited to the telescope demonstrate the scientific power and breadth infrared astronomy offers. Even after the observatory runs out of liquid helium to keep all its detectors at prime sensitivity, Spitzer will continue to explore the infrared universe. And new and powerful infrared space observatories will soon carry on Spitzer's work.

Big chill

The secret of Spitzer's success is a design that maintains the telescope's cameras and spectrographs at temperatures as low as –458° Fahrenheit (–272° Celsius), where electronic detectors achieve their maximum sensitivity to infrared light. The observatory's instruments sit atop a tank of liquid helium coolant. Innovative engineering helps isolate the telescope from external heat sources that could blind its instruments.

For example, the observatory's side-mounted solar panel and heat shield points toward the Sun at all times, keeping the telescope in continuous shadow. Spitzer's Earth-trailing orbit maintains a cool distance from our planet's warmth. The telescope's physical design also takes advantage of the space environment's natural refrigerating action. It takes just 1 ounce of helium per day to chill Spitzer's instruments to operating temperature.

However, the telescope's engineering innovations can only slow, not stop, the inexorable boiling away of the helium. NASA



A detailed infrared portrait of the Orion Nebula by NASA's Spitzer Space Telescope highlights the thick gas and dust that gives birth to myriad stars. The telescope's camera operates in multiple wavelengths in the infrared spectrum, exposing different features of the nebula: star-warmed dust (red and orange), hot gas (green), and starlight (blue). NASA/JPL-Caltech/ S. Thomas Megeath (University of Toledo

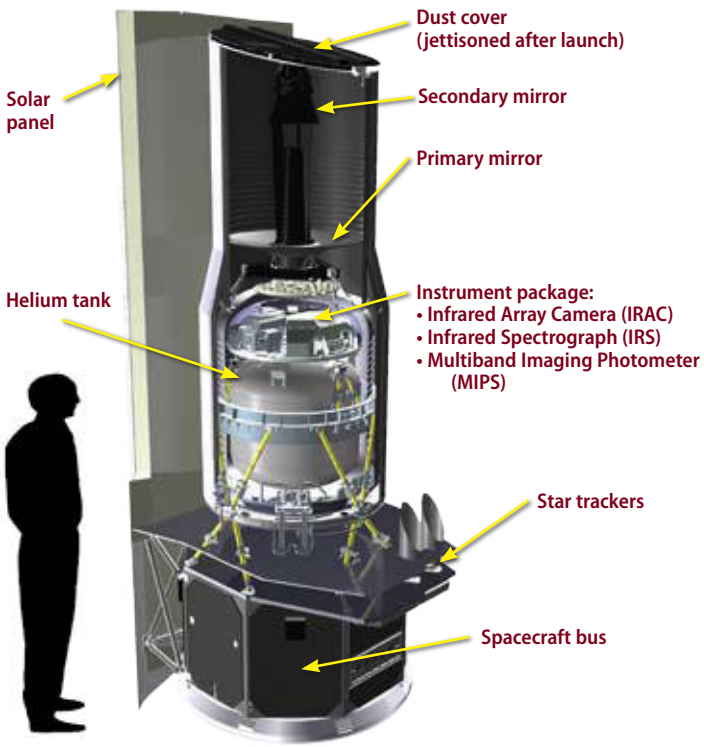
Five perspectives on the Spitzer Space Telescope display features of the observatory that keep its sensitive infrared detectors cool. The sun shield/solar panel keeps the telescope barrel in eternal shade. The side of the telescope always facing away from the Sun is painted black to radiate heat into space. NASA/JPL-Caltech

predicts that the last of the original 95 gallons (360 liters) of cryogen will be gone some time around April 2009. This will mark the end of more than 5 years of Spitzer's helium-cooled "cold mission" that began in 2003.

Exoplanet weather report

Spitzer's cold mission overlapped an exciting period of exoplanet science. As of early December 2008, astronomers had found 333 confirmed exoplanets orbiting some 283 relatively nearby stars. Additional finds seem to come on a weekly basis.

Many of the known exoplanets are "hot Jupiters," or massive gas planets orbiting close to their parent stars. One of these planets, called HD 189733b, orbits a star 63 light-years from Earth. The planet radiates most of its light in the infrared, allowing Spitzer to probe its temperature and composition.



Spitzer's instruments and their infrared detectors rest atop a tank of liquid helium, which chills the electronic devices to keep them at maximum sensitivity. The helium-cooled core is physically isolated from the octagonal spacecraft "bus," where electronics gear generates heat. Ball Aerospace

HD 189733b's relatively weak glow is lost in the glare of its parent star. But Spitzer was still able to isolate the planet's light, thanks to the fact that HD 189733b's orbit lies edge-on as seen from Earth. (See illustration, page 48.)

With each orbit, the planet passes in front of (transits) the star and swings around its side before passing behind the star. When the planet disappears from view, Spitzer's sensitive detectors measure a slight drop in the infrared light coming from the star. That tiny blip in the signal represents the temperature of the planet's atmosphere.

"New GLIMPSE data strongly confirmed previous evidence that **the Milky Way is a barred spiral galaxy.**"

But Spitzer researchers can also map how temperature varies by longitude across the planet's gaseous surface. Because HD 189733b orbits so close, the star's powerful gravity holds one side of the planet toward it at all times — just as Earth's gravity keeps the same hemisphere of the Moon always facing us.

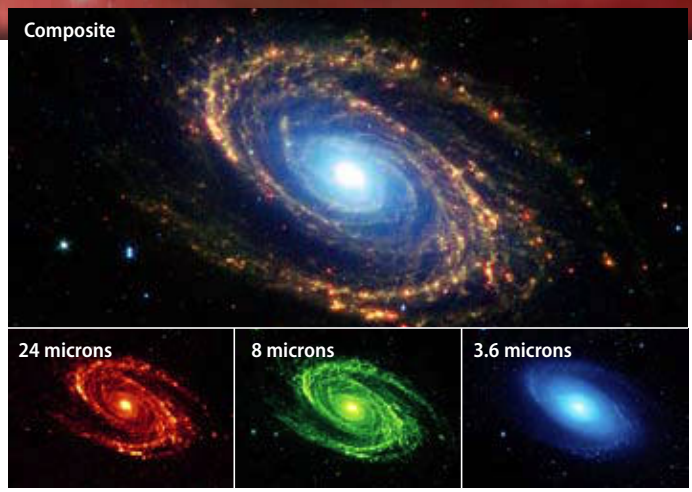
As HD 189733b transits its star, Spitzer observes its nightside. As the planet finishes a transit and begins to swing around the star's backside, Spitzer sees a slightly different portion of the atmosphere from moment to moment. By the time the planet passes behind the star, the telescope will have measured the infrared light emitted along the atmosphere's entire circumference, revealing how temperatures vary with longitude.

One thing these studies revealed is that temperatures on the day and night sides don't vary dramatically — from 1700° F (927° C) to 1200° F (649° C) — despite the planet's lack of rotation. Also, the hottest point on the dayside is not "high noon," with the star directly overhead. Instead, the hot spot is shifted about 30° east of high noon.

The 30° offset and the modest difference between day and night temperatures suggest that winds redistribute heat from the dayside to the nightside. Winds at speeds exceeding 1,000 mph (1,610 km/h) could explain the temperature patterns.

NOAO/NASA/JPL-Caltech/J. Rho (SSC/Caltech)

The Trifid Nebula (M20) in visible light (left) contrasts sharply with Spitzer's infrared portrait (right), revealing different features and processes. Visible light highlights the Trifid's famous dust lanes. The infrared image lifts the veil of dust, exposing new stars forming within gas.



Three infrared wavelengths capture different features of the galaxy M81. For example, infrared at 3.6 micrometers traces the distribution of stars in the galaxy's central bulge and spiral arms, while the 24-micrometer image emphasizes the glow of warm dust. NASA/JPL-Caltech/K. Gordon (U. Arizona)/S. Willner (CfA)

Exploring the Milky Way

Spitzer observations have also contributed tremendously to understanding our own galaxy, the Milky Way. Spiral arms rich in gas and dust dominate coffee-table-book photographs of other spiral galaxies, but obtaining a similarly rich portrait of our own is thwarted by the fact that we live within it. Infrared astronomy offers a solution.

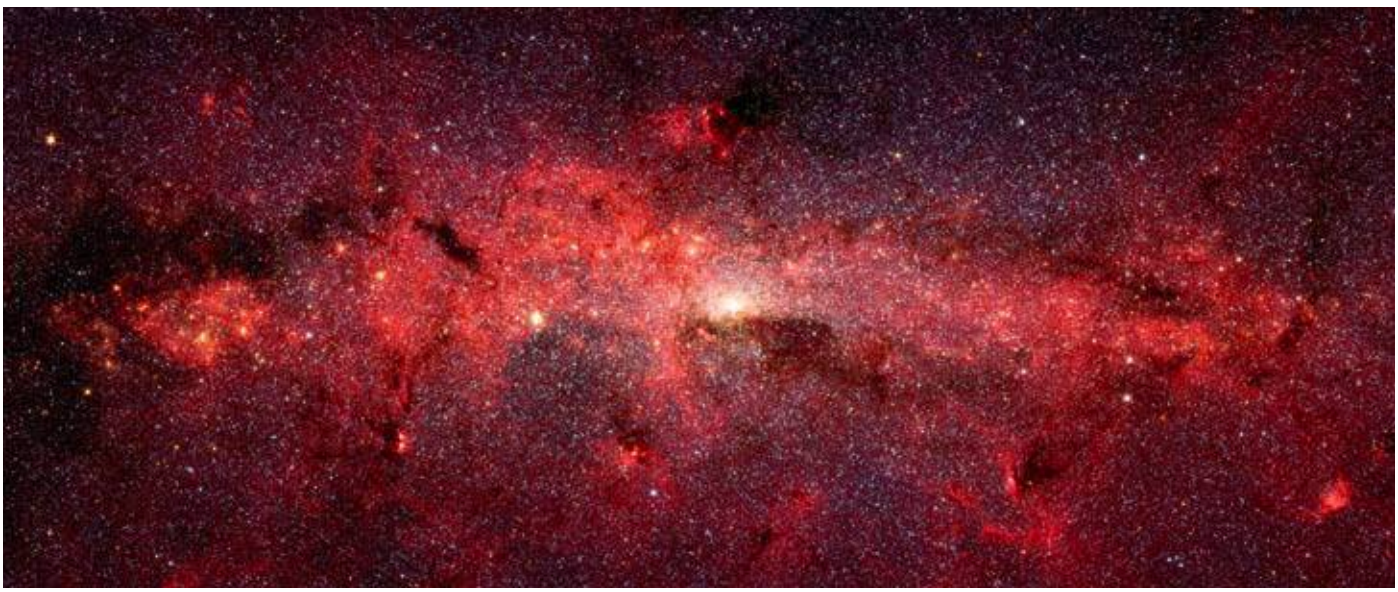
At visual wavelengths, counting stars to map the galaxy's arms and other major structures becomes more difficult with distance. Most of the galaxy's stars lie within its plane, but so does most of the dust. Visible light from stars more than about 3,000 light-years from Earth cannot penetrate the veil. Meanwhile, the center of the galaxy lies some 27,000 light-years away. Fortunately, most infrared wavelengths pass right through the dust, making the Milky Way's disk visible to Spitzer.

Important advances in mapping the Milky Way came out of Spitzer's execution of the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) survey. During GLIMPSE, Spitzer surveyed a 130°-long strip stretching 1° above and below the galactic plane, or an approximate total height of four Full Moons stacked top to bottom.

The flood of new GLIMPSE data strongly confirmed previous evidence that the Milky Way is a barred spiral galaxy. The bar, about 28,000 light-years long, represents stars and gas that orbit the galactic center in elliptical rather than circular paths.

Before GLIMPSE, observations suggested the galaxy sported four prominent or "major" arms called Norma, Perseus, Sagittarius, and Scutum-Centaurus. Spiral arms are longer than they are wide, so Spitzer sees more stars when looking along the arms' length than across them.

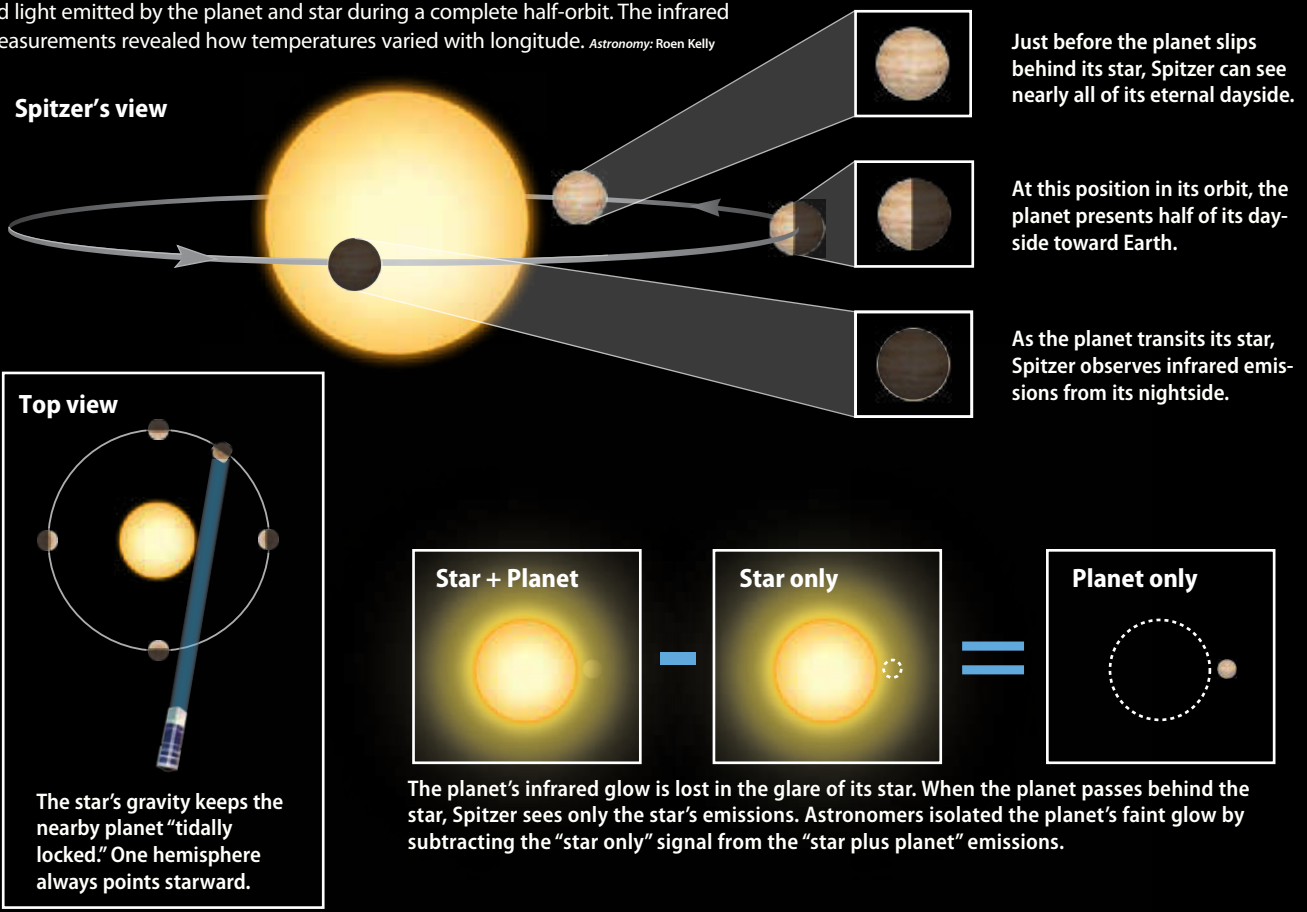
Astronomers with GLIMPSE saw no jump in stellar density along the Sagittarius and Norma arms. These structures are now relegated to "minor arms" composed of patches of gas and pockets of young stars. But Scutum-Centaurus and Perseus



Hundreds of thousands of stars crowd the Milky Way's central region. Dust blocks the visible wavelengths from this area, but infrared imaging lifts the veil. In this false-color view, old and cool stars are blue. Reddish coloring indicates dust illuminated by the light from hot, massive stars. NASA/JPL-Caltech/S. Stolovy (SSC/Caltech)

How the Spitzer Space Telescope took an exoplanet's temperature

Using the Spitzer Telescope, researchers mapped temperatures on the surface of exoplanet HD 189733b as it circled its star. To do that, the telescope collected infrared light emitted by the planet and star during a complete half-orbit. The infrared measurements revealed how temperatures varied with longitude. *Astronomy:* Roen Kelly


Spitzer's view
Just before the planet slips behind its star, Spitzer can see nearly all of its eternal dayside.
At this position in its orbit, the planet presents half of its dayside toward Earth.
As the planet transits its star, Spitzer observes infrared emissions from its nightside.
Top view
The star's gravity keeps the nearby planet "tidally locked." One hemisphere always points starward.
Star + Planet
Star only
Planet only

The planet's infrared glow is lost in the glare of its star. When the planet passes behind the star, Spitzer sees only the star's emissions. Astronomers isolated the planet's faint glow by subtracting the "star only" signal from the "star plus planet" emissions.

survived as star-rich major arms that trail from either end of the central bar, just as in other barred spirals.

Finding hidden black holes

Spitzer's ability to see through shrouds of dust in galaxies has raised new questions about which galaxies harbor supermassive black holes. Until recently, virtually all such black holes were found in galaxies with central concentrations of stars called galactic bulges. The Milky Way Galaxy, for example, has both a central bulge and a supermassive black hole of 3 to 4 million solar masses. Elliptical galaxies, which resemble the central bulges of spiral galaxies, also host large black holes. The largest examples contain up to billions of solar masses.

Astronomers noticed that central black holes and bulges seem to grow together. The more massive the bulge, the bigger the black hole. In a remarkable but unexplained relationship, central black holes contain about 0.2 percent (1/500th) of the central bulge's mass. As for galaxies without bulges, they should not have central black holes, but recent Spitzer explorations of "bulgeless" galaxies proved this wrong.

In one study, researchers used Spitzer to peer into 32 galaxies with relatively small or imperceptible bulges. Unexpectedly, seven of them harbored substantial black holes, ranging from 3,000 to 150,000 solar masses. Thus, it appears possible that galaxies without bulges can form and grow black holes after all.

Infrared astronomy proved critical in these observations. As gas spirals around a black hole's whirlpool-like accretion disk, X-ray and ultraviolet emissions energize neon gas in the accretion disk. This produces a unique infrared signal that passes through dust enshrouding the galaxy. Spitzer can see it.

The Spitzer black hole observations leave us with a fundamental unanswered question. If galactic bulges don't create black holes, what does? For now, astronomers can only speculate. Spitzer and other infrared observatories may help solve the puzzle by undertaking a much more complete census of central black holes in nearby galaxies.

Looking deep

Spitzer has provided some of the deepest looks at the early universe, when the first stars and galaxies formed. We haven't come close to the longest "look back" time possible — 13.7 billion years ago, when the Big Bang created the cosmos. But Spitzer has already pushed its observations into a critical period of the universe's history: the epoch of reionization.

NGC 5907: NASA/JPL-Caltech/M.L.N. Ashby (CfA); Sombrero: NASA/JPL-Caltech/Hubble Heritage Team

Astronomers once thought flattened spiral galaxies lacking prominent central bulges, like NGC 5907 (left), also lacked central black holes. Galaxies with substantial bulges, like the Sombrero Galaxy (right), generally do have black holes. But recent Spitzer observations have challenged the bulge-black hole link.

Right after the Big Bang, all matter in the universe was a hot, electrically charged (ionized) stew of protons, electrons, and photons. Then, about 380,000 years after the Big Bang, the universe expanded and cooled enough to enable the ionized particles to recombine, forming neutral hydrogen and helium atoms but no stars. This marked the "Dark Ages" of the universe.

Then, out of the darkness, stars and galaxies began to form. As new stars ignited, their radiation began to heat and reionize the hydrogen gas. By about 1 billion years after the Big Bang, the reionization was largely complete. Today, most matter between galaxies remains ionized hydrogen. But astronomers don't know exactly when this crucial process began.

We can look back toward the age of reionization by observing the most distant objects in the universe — early galaxies — and checking to see whether they lie within neutral or ionized intergalactic matter. This would allow us to chart the process of reionization and the evolution of cosmic structure.

"Spitzer's farthest frontier is the early universe, the period **when the first stars and galaxies formed.**"

Cosmic expansion stretches the light from distant galaxies. It arrives at Earth with a pronounced lengthening, or redshift, of its wavelength toward the infrared. Spitzer is attuned to just these wavelengths. The higher the redshift of an object's light, the further back in cosmic time we see it.

High-redshift galaxies are time capsules that can reveal processes at work early in cosmic history and how they shaped subsequent events. Spitzer commonly observes galaxies at a redshift of 6. That means the light from these galaxies left about 900 million years after the Big Bang. This period overlaps the epoch of reionization.

Working in tandem with the Hubble Space Telescope and large ground-based observatories, Spitzer continues to push further back in cosmic time. The telescope has observed galaxies that may lie at a redshift as high as 7.6, or roughly 700 million years after the Big Bang. Stars in such galaxies may have formed as early as 500 million years after the Big Bang.

One mystery we'd like to solve is the apparent shortfall in radiation required to reionize the universe. The number of galaxies we observe at high redshifts could not have radiated enough energy to ionize all the neutral hydrogen gas in the early universe. The shortfall is by a factor of three.

One possible explanation is that a large number of lower-mass galaxies existed alongside the brighter high-mass galaxies. Although the lower-mass galaxies weren't nearly as powerful as their gargantuan cousins, they might have collectively produced enough radiation to fully reionize the universe. We can't see these low-mass galaxies even if they exist — they are too dim.

Spitzer's warmer future

Soon we will be able to see still further in cosmic time — again with the help of infrared space astronomy. Spitzer's successor is NASA's James Webb Space Telescope (JWST), slated for launch in 2013. The observatory's light-collecting surface is 50 times that of Spitzer, promising views of the early universe at higher redshifts than Spitzer can obtain.

But don't forget about Spitzer just yet. Even after the last of the observatory's liquid helium evaporates, it will still be able to remain cool enough to operate in two infrared bands at full sensitivity. At these wavelengths, Spitzer will still be able to observe exoplanets, study the Milky Way and outer solar system, and search for distant galaxies.

Spitzer's "warm mission" will last for at least 2 years. The cycle of exploration, discovery, analysis, and understanding begun by the fully chilled Spitzer will continue well into the next decade. If Spitzer was the warm-up for the next leap of infrared astronomy, the main event should be quite a show.

Learn more about the Spitzer Space Telescope's past discoveries at www.Astronomy.com/toc.

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

Journey inside a dark nebula

Q: What would we see if the solar system were located in a dark nebula like the Coal Sack? Would things look much different from inside a bright nebula such as the Orion? — Z. D. Meachum, Jr., Bossier City, Louisiana

A: Inside the Coal Sack, dust would obscure the background stars. Inside the Orion Nebula, luminous young suns would appear as bright as Jupiter and Venus.

Typical dark nebulae such as the Coal Sack contain relatively dense gas and dust. If our solar system were to pass through such a dark cloud, our view of bright, nearby objects such as the Sun, Moon, and planets would be largely unaffected.

However, the nebula's dust would dim and redden light from distant stars. In a particularly dense cloud, stars and faraway galaxies would disappear completely. Some of the Sun's light would be scattered back toward Earth by clumps, sheets, and filaments of gas in the cloud's interior. The night sky would glow faintly with a lumpy and iridescent blue light.

If the Sun were to pass through a region such as the Orion Nebula, massive stars within the cloud would look like blue-white diamonds, comparable in brightness to the Full Moon. Thousands of young stars would be sprinkled like jewels across our sky. Many would shine as brightly as Jupiter or Venus.

A dense cloud of dust and gas called the Coal Sack in the Southern Cross blocks out many of the stars behind it, appearing to create a hole in the southern Milky Way. Luke Dodd

Radiation from the bright stars would energize gas in the nebula, setting the night sky aglow with gossamer green and turquoise filaments and gas bubbles shining in the light of ionized oxygen. In the brightest parts of the nebula, our eyes would just make out the red glow of atomic hydrogen, ionized sulfur, and neutral oxygen. In short, our sky would never be truly dark at night. We would not see the distant stars and galaxies. **— John Bally,** University of Colorado at Boulder

BEYOND PLUTO

Q: What bodies beyond Pluto will the New Horizons probe investigate? — Douglas Kaupa, Edwards, California

A: After visiting Pluto and its moons in 2015, the New Horizons spacecraft will continue farther into the Kuiper Belt — the region of icy bodies of which Pluto is a member. Mission scientists haven't determined yet which Kuiper Belt objects (KBOs) New Horizons will visit. They will do so by the time the spacecraft reaches Pluto.

None of the approximately 1,000 known KBOs will be at the right place at the right time along New Horizons' predicted path through the Kuiper Belt. The spacecraft can make only minor course changes, so timing is critical.

Astronomers will use telescopes on Earth to search for KBOs New Horizons may be able to visit. The pool of candidates includes the estimated 500,000 KBOs larger than 25 miles (40 kilometers) in diameter. These are large enough for a telescope on Earth to resolve.

KBOs are moving toward the spacecraft's projected path at various speeds and trajectories. New Horizons is still 6 years from a rendezvous, so the candidates are still relatively far away from the points at which they might cross the spacecraft's path. Finding them would require searching a large region of the sky, which takes too much telescope time. Mission scientists are waiting until 2011 to start the search in earnest. Then, the search region will be narrower.

New Horizons should be able to reach one or two KBOs with diameters of tens of miles. A preliminary search in 2004 and 2005 with the Subaru Telescope in Hawaii provided data the mission team is now using to hone techniques for distinguishing dim KBOs from the background stars. **— John Spencer,** Southwest Research Institute, Boulder, Colorado

BRIGHTEST BLAST

Q: What was the most powerful supernova blast ever seen?

— **Samuel Heinitz,** Edmond, Oklahoma

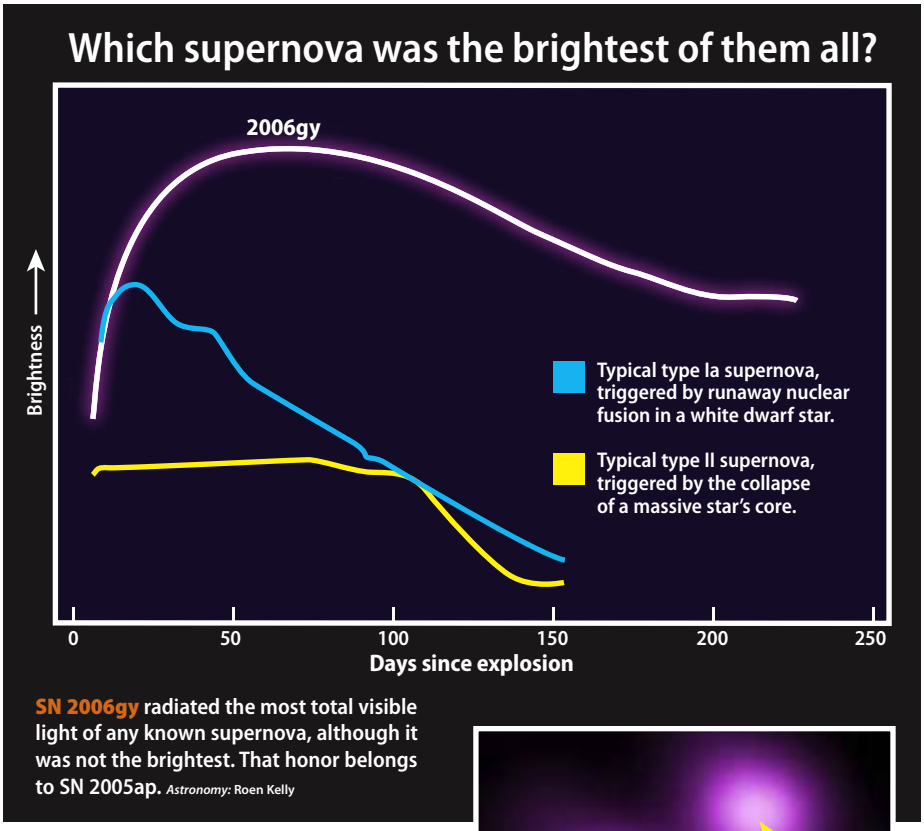
A: The brightest supernova ever observed was SN 2005ap. However, SN 2006gy radiated the highest total visible light.

Focusing on the visible light from a supernova, we can measure its radiant power by observing how much energy per second reaches our telescopes. Then, factoring in the supernova's distance, we can determine the amount of energy emitted by the supernova itself.

Using this method, we can say the most intrinsically luminous supernova was SN 2005ap. It peaked at a brightness comparable to 100 billion Suns.

The following year, SN 2006gy achieved the record for emitting the greatest total energy in the form of visible light. It reached a lower peak brightness than SN 2005ap, but held its brilliance for much longer.

Think of SN 2005ap as a 100-watt bulb and SN 2006gy as a 60-watt that was left on much longer. SN 2005ap made the room brighter, but SN 2006gy racked up a larger electric bill. — **Robert Quimby,** California Institute of Technology, Pasadena



SN 2006gy radiated the most total visible light of any known supernova, although it was not the brightest. That honor belongs to SN 2005ap. *Astronomy:* Roen Kelly

Supernova 2006gy shines as brilliantly in X-ray light as the core of its host galaxy, NGC 1260, in this Chandra X-ray Observatory image.

NASA/CXC/UC-Berkeley/N. Smith

EXTREME PHYSICS

Q: I've read about stellar explosions propagating at "supersonic speed." On Earth, supersonic means faster than the speed of sound. How does this idea apply to stars? — **Paul Marsh,** Weare, New Hampshire

A: The shock wave from an exploding star, or supernova, moves at a much higher velocity than pressure disturbances normally travel through the gaseous material between the stars, known as the interstellar medium (ISM). That normal velocity — whether the pressure disturbance is a sound or the expanding shell of debris from a supernova — is a medium's sound speed. **Stellar blasts are supersonic because they move faster than the ISM's sound speed.**

The ISM is mostly hydrogen gas at –280° Fahrenheit (–173° Celsius). Its sound speed is about 3,000 mph (4,830 km/h). Compare that with the sound speed on Earth at sea level: a mere 767 mph (1,234 km/h).

A supernova presses outward on the ISM at about 36 million mph (58 million km/h), far faster than the ISM's sound speed. It is therefore supersonic, or "greater than the speed of sound."

— **Bruce Balick,** University of Washington, Seattle

GALAXY MERGERS

Q: After the Andromeda and Milky Way galaxies finish merging in a few billion years, what will happen to the other galaxies in the Local Group? — **Louis Brechemin,** Media, Pennsylvania

A: The Local Group is a cluster of galaxies bound to each other by gravity. The largest are the Milky Way, Andromeda (M31), and the Pinwheel Galaxy (M33). Smaller dwarf galaxies make up most of the rest.

As Andromeda and the Milky Way merge into a single object, nicknamed "Milkomeda," the other galaxies will probably remain bound gravitationally within the Local Group, with Milkomeda at the center. I say "probably" because of uncertainties about the group's combined mass and the motions of its various members relative to each other.

The uncertainties mean we cannot say for certain whether the dwarf galaxies are truly gravitationally bound to the Local Group or are just passing by. The galaxies outside the Local Group, far beyond Andromeda, are not bound to us and will eventually exit from view. — **Abraham Loeb,** Harvard University, Cambridge, Massachusetts

What is the difference between a nova and a supernova? Listen at www.Astronomy.com/toc.

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Discover galaxy groups and clusters

With an 8-inch or larger scope and a dark sky, go after these distant citizens of the cosmos.

by Steve Coe

It's springtime, and that means galaxies. Because Earth's orbit faces away from the densest part of the Milky Way during spring, galaxies abound.

All galaxies formed from large gaseous clouds compressed by gravity. The most massive produced groups and clusters. Galaxy groups contain between three and 50 galaxies. Astronomers designate them in two ways. One is by the Messier or NGC number of the group's brightest galaxy. Examples include those named after M66 and NGC 4565. The other designation comes from a professional investigator of galaxies, Canadian astronomer Paul Hickson. He cataloged 100 groups now known as Hickson Compact Galaxy Groups (Hickson).

Galaxy clusters typically contain more than 50 galaxies, but often many more. The largest galaxy clusters hold thousands of star cities. The biggest clusters of galaxies are the universe's largest objects. American astronomer George Ogden Abell (1927–1983) cataloged 2,712 of these huge objects, and therefore each carries the designation Abell Galaxy Cluster (Abell).

Locating and observing distant galaxy groups and clusters proves difficult for an amateur astronomer armed with only a small telescope. Few of these objects are worth chasing with less than 8 inches (200 millimeters) of aperture.

Another limitation is the sky. Faint groups of distant galaxies are difficult to spot in poor weather or in light-polluted areas. The glow of artificial lighting lowers the contrast between dim galaxies and the night sky. So, drive away from the city for the best results.

Abell 1656 in Coma Berenices contains more than 800 galaxies brighter than magnitude 16.5. Through a 12-inch scope, you'll spot the three brightest galaxies and about a dozen fainter ones. Bernhard Hubl

Begin in Boötes

The constellation of the Herdsman contains two small galaxy groups. First is the **NGC 5797 Group**.

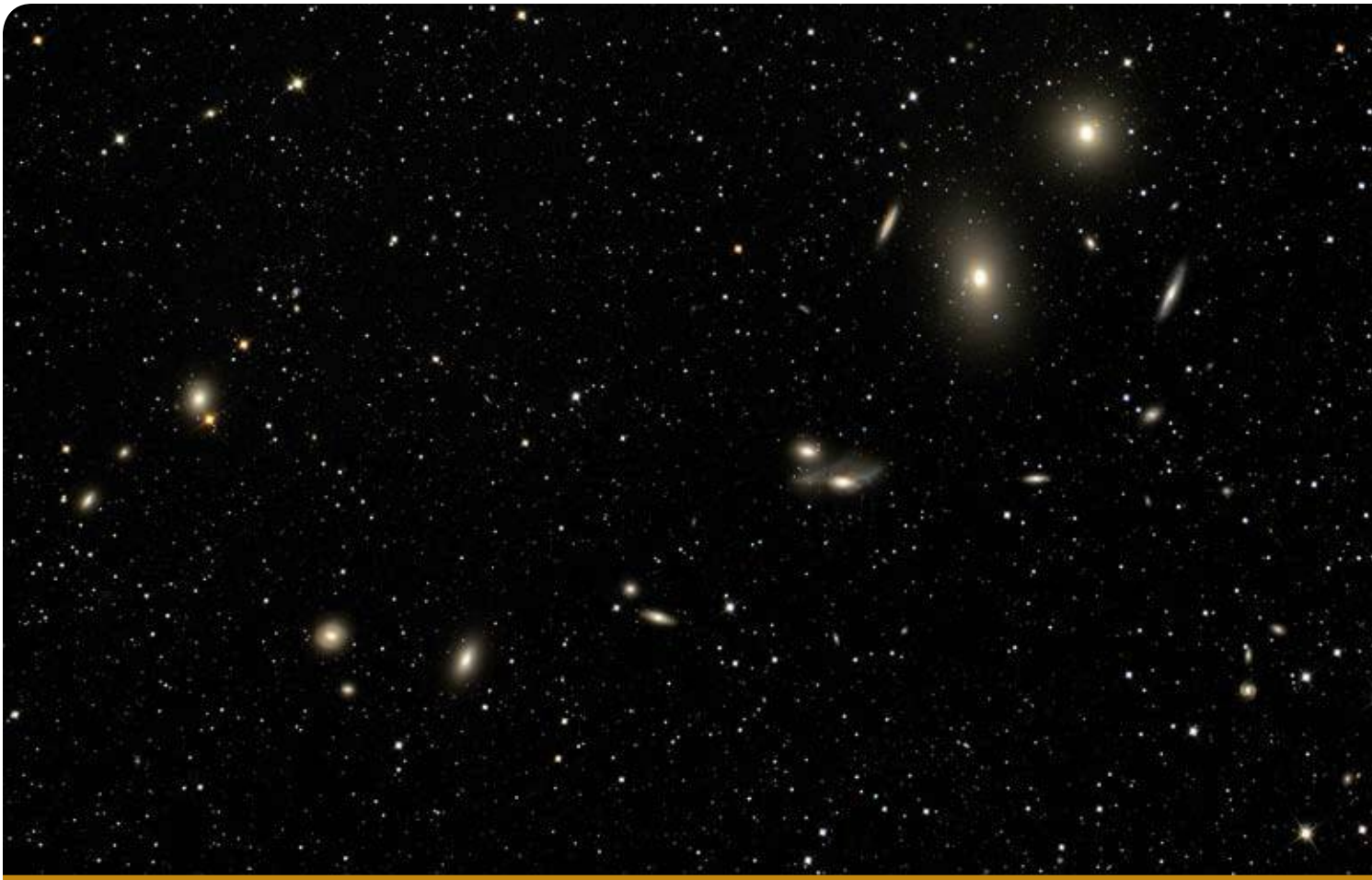
Using a 13-inch Newtonian reflector at a dark site, NGC 5794 appears faint, small, round, and a little brighter in the middle at 135x. NGC 5795 is also faint and small but elongated 2½ times longer than it is wide toward the east-southeast.

The group's namesake, NGC 5797, looks brightest in the middle and large. It's elongated in an east-west direction. One of this group's other galaxies, NGC 5804, forms a row of three with NGC 5797 and NGC 5794. I could not see NGC 5805, 2.5' south-southeast of NGC 5804, on a night I rated 6 out of 10.

Boötes' other galaxy group is the **NGC 5899 Group**. At 100x through the 13-inch scope, the group's namesake looks bright, large, and 3 times as long as it is wide. It's also much brighter in the middle with an almost stellar nucleus. NGC 5900 lies to the north of NGC 5899 and is faint and round. NGC 5895 looks faint, small, and a bit elongated.

The NGC 5350 Group (Hickson 68) has a magnitude 11.3 spiral galaxy as its namesake (topmost of group). More compact NGC 5353 (at the bottom of the group), however, shines 0.2 magnitude brighter. NGC 5371, the spiral to the left of center, isn't part of the group. Bernhard Hubl

Steve Coe *is a member of the Phoenix Saguaro Astronomy Club. His most recent book is* Observing Nebulae *(Springer, 2008).*



Markarian's Chain is one of the sky's best-known galaxy groups. It lies mainly in Virgo but stretches over the border into neighboring Coma Berenices as well. The two brightest members are elliptical galaxies M84 (upper right) and M86, to M84's lower left. Rich Jacobs

Continue to Canes Venatici

The **NGC 5350 Group** (Hickson 68) is tightly bunched and contains several galaxies that appear bright through the 13-inch telescope. You'll see NGC 5350 as large, twice as long as it is wide, and much brighter in the middle at 135x.

NGC 5353 is the other bright galaxy. It is smaller than NGC 5350, 50 percent longer than wide, and brighter in the middle. All the other galaxies in this group are easier to see at 220x.

NGC 5354 is faint, small, and round. NGC 5355 is similar to NGC 5354, though it appears smaller. It is twice as long as it is round and a little brighter in the middle. NGC 5358 is fainter, smaller, and equally stretched out. One other interesting feature is a yellow and blue double star in the field of view.

Cavort to Coma Berenices

The first of our spring galaxy clusters is one of the sky's best. **Abell 1656**, the Coma Cluster of Galaxies, contains hundreds of distant galaxies within several fields of view. Swiss astronomer Fritz Zwicky (1898–1974) identified an amazing 804 galaxies in this cluster brighter than magnitude 16.5, so don't worry about running out of goodies to observe.

NGC 4884 and NGC 4874 occupy this rich cluster's center. NGC 4884 has a bright core that stands out. On a good night I see it as faint, small, and with a brighter middle. It's 80 percent longer than it is wide as seen at 150x through the 13-inch. The background appears blotchy from the profusion of fainter galaxies. Using a dark hood over my head, I can pick out five faint members and 20 even-fainter ones on an excellent night.

Moving up to a friend's 36-inch Newtonian reflector makes a big difference. Using a 20mm eyepiece (229x), I count 126 galaxies within one field of view on each side of Abell 1656's center. The central section alone contains 42 galaxies, including two bright ones and lots more, with details visible in the brighter members — dark lanes and arms. Every shape, size, and tilt is there to see. Averted vision reveals hundreds more galaxies. Pushing the scope 5 fields of view away shows me that the gray background I saw

Hickson 61 is the Box. Each of the four galaxies sits at the corner of a long rectangle. The brightest, NGC 4169, shines at only magnitude 13.3, so use a big scope to observe this group. The Box lies in Coma Berenices. Martin C. Germano

Just seeing Abell 2065 in Corona Borealis is a feat because this galaxy cluster lies 950 million light-years away. Although hundreds of galaxies crowd this image, expect to see only about a dozen through a 20-inch telescope. Use a magnification around 300x. Tony and Daphne Hallas

was the result of unresolved galaxies lightening the field of view. This is a "wow" view if there ever was one.

Hickson 61 is a fascinating alignment of galaxies. I first heard of it as the NGC 4169 Group, also known as the Box.

Through the 13-inch at 150x, NGC 4169 appears large, brighter in the middle, and slightly elongated south-southeast to north-northwest. Two large and elongated galaxies, NGC 4173 and NGC 4175, form the Box's longest side. NGC 4174 is small and somewhat elongated; it is at a right angle to the elongated pair. The shape of this galaxy group is unique.

Cross over to Corona Borealis

Abell 2065 is the Corona Borealis Galaxy Cluster. Even through a 20-inch reflector, the view is not spectacular, but realizing what you are seeing is amazing.

Through a 22mm eyepiece (115x), I count 11 small, faint galaxies. Two of these tiny galaxies are brighter than the rest, but none is easy to observe. The faintest galaxies come and go with the seeing. One or two have a somewhat brighter middle, but not by much.

Even so, you are viewing galaxies 950 million light-years away from Earth. Much has happened while that light traveled to your eye.

Hop down to Hydra

Abell 1060 offers a rich field of galaxies even through a medium-sized telescope. At a site 100 miles (163 kilometers) from the lights of Phoenix, using my 6-inch refractor at 87x and an observing hood, I can see five galaxies with direct vision and another six with averted vision.

Previously, I had made a more detailed observation of this cluster using my 13-inch scope. I did the following observations at 165x.

NGC 3285 is faint, pretty small, somewhat brighter in the middle, and somewhat elongated. Averted vision makes it stand out better. MCG 04–25–026 and MCG 04–25–025 are faint, a little elongated, and have brighter cores.

NGC 3305 is small and round. NGC 3308 looks faint, somewhat elongated, and has a slightly brighter middle. NGC 3309 is small and round and boasts a prominent star lying on the east side.

NGC 3311 and NGC 3312 appear small and somewhat brighter in the middle. NGC 3314 is faint and elongated. I see it with averted vision only.

NGC 3315 and NGC 3316 both are round and have somewhat brighter middles. NGC 3390 is large and elongated 4 times as long as it is wide.

MCG 04–25–050, IC 2597, and MCG 04–25–052 all appear extremely faint, small, and round, and emerge with averted vision only.

Looking in Leo

Abell 1367 is a faint target for medium-sized apertures. If you have a 10-inch scope and are looking for a challenge, Abell 1367 can provide one.

Through the 13-inch scope at 135x, I can pick out two faint galaxies with slightly brighter cores — NGC 3842 and NGC 3861 — and four very faint companions. They are so dim that turning on a red light to draw them makes them disappear for several minutes until my night vision returns. Ten other member galaxies lie within 1° of this field.

Leap up to Leo Minor

The **NGC 3158 Group** contains one bright central galaxy and a sprinkling of fainter

A quick guide to galaxy groups and clusters

Object	Con.	R.A.	Dec.	Notes
NGC 5797 Group	Boötes	14h56m	49°42'	Contains NGC 5797 and NGC 5804
NGC 5899 Group	Boötes	15h15m	42°03'	Contains NGC 5895 and NGC 5900
Hickson 68	Canes Venatici	13h53m	40°22'	Brightest member is NGC 5350
Abell 1656	Coma Berenices	13h00m	27°59'	NGC 4884 lies in the center
Hickson 61	Coma Berenices	12h12m	29°11'	Known as the Box
Abell 2065	Corona Borealis	15h23m	27°43'	The Corona Borealis Galaxy Cluster
Abell 1060	Hydra	10h37m	–27°32'	Contains NGC 3309 and NGC 3311
Abell 1367	Leo	11h45m	19°42'	Contains NGC 3842 and NGC 3861
NGC 3158 Group	Leo Minor	10h14m	38°46'	Contains NGC 3159 and NGC 3163
NGC 3166 Group	Sextans	10h14m	3°26'	NGC 3169 is the other bright galaxy
Markarian's Chain	Virgo	12h26m	12°57'	Contains M84 and M86

Key: Con. = constellation; R.A. = right ascension (2000.0); Dec. = declination (2000.0) Mag. = magnitude

The NGC 3166 Group in Sextans contains two bright galaxies and several fainter ones. The brightest are magnitude 10.3 NGC 3169 (left of center) and magnitude 10.5 NGC 3166 (right of center). The next brightest is magnitude 13.9 NGC 3165 (at the lower right of NGC 3166). Ken Crawford

galaxies all around. Through the 13-inch at 150x, NGC 3158 appears faint, small, and round. It grows suddenly brighter in the middle. This galaxy grows larger with averted vision. Five other galaxies share the field of view. The two to the north are NGC 3152 and NGC 3160. Both are faint and small, but NGC 3160 is 3 times as long as it is wide, while NGC 3152 is round with a somewhat brighter center. The three galaxies to the south are NGC 3151, NGC 3159, and NGC 3163. All are faint and small, with NGC 3151 a little elongated.

Skip over to Sextans

The **NGC 3166 Group** has four members with NGC numbers and stretches northeast to southwest. It has a background of unresolved galaxies. I observed this group at 100x and 200x through an 11-inch Schmidt-Cassegrain telescope on a night I rated 8 out of 10 for transparency.

The westernmost galaxy, NGC 3156, appears faint and small with a somewhat brighter core. NGC 3165 is small and round and is the group's most difficult galaxy to see. NGC 3166, by contrast, looks bright, large, nearly twice as long as it is wide, and suddenly much brighter in the middle with a bright core. NGC 3169 has barely visible spiral arms and a dust lane offset from its center. I found the dust lane easy to see.

AGC 1367 in Leo may look dense in this image, but it's a faint target. The brightest galaxy, NGC 3842, glows weakly at magnitude 13. Svend and Carl Freytag/Adam Block/NOAO/AURA/NSF

Veer off to Virgo

You didn't think I was going to write an article on spring galaxy groups and leave out Virgo, did you? The two huge elliptical galaxies M84 and M86 lie near the center of the **Virgo cluster**. Several other nearby galaxies form a galactic "smiley face." NGC 4388 is the elongated mouth, NGC 4387 marks the faint nose, and NGC 4402 is the left eyebrow.

Starting from this famous area, a 2°-long curved line of galaxies ends over the Coma Berenices border with the barred spiral NGC 4477. This northeast-to-southwest band of bright galaxies is named for Georgian astronomer Beniamin Markarian (1913–1985). In 1961, he published a paper that discussed this arc of galaxies and concluded it was a gravitationally bound system. Ever since, this chorus line of galaxies has been called Markarian's Chain.

The Chain is the beginning of several celestial hops that can take you to a variety of bright galaxies and small galaxy groups. I like moving to the southeast and finding M87, another huge elliptical galaxy, then hitting M58, a spiral that shows little detail through the 13-inch at 220x. From M58 you can move to the south to see the Siamese Twins (NGC 4567 and NGC 4568). At 150x, these two galaxies form a V-shaped pair.

Markarian's Chain is just one of many paths to take among spring's myriad galaxies. If your sky is dark enough and your scope large enough, galaxy groups and clusters will provide you with hours of observing joy.

Find a guide to 10 more galaxy groups and clusters at www.Astronomy.com/toc.

How to build a backyard observatory

A permanent telescope setup gives you fast and easy access to the sky.

by Michael E. Bakich

The best thing I've done as an amateur astronomer was construct a small observatory in the backyard of a house I used to own. When the observing bug struck, I could retract the roof and be at the eyepiece in 3 minutes. Because the telescope remained outdoors, it was already at the right temperature and polar aligned. Furthermore, I didn't have to lug an optical tube, a mount, counterweights, and accessories anywhere. From a seated position inside the house, I was ready to observe before my eyes were even dark-adapted.

If you're an amateur astronomer who doesn't observe as often as you'd like because of the work involved, consider building an observatory. And think about this side benefit for the whole family: reclaimed storage. All your "stuff" that normally would be in the house resides safely outside in the observatory.

A friend once told me about his setup. He spent 3 hours lugging out the gear, setting up, and doing a rough alignment followed by a more precise drift alignment. At that point, he would set up the computer and the CCD camera. By then the scope had reached thermal equilibrium (outside temperature). That's when he checked the collimation (optical alignment), made any adjustments, and then he was finally working.

Wow. That's a level of dedication few amateurs can muster. Think of how much time my friend could save if he had an observatory. Such a facility, however, doesn't just appear. You have to build it, and lots of decisions lie along the way.

Michael E. Bakich *is a senior editor of* Astronomy.

Choose your site

Your first task is to select the best location for the observatory. This can be 20 feet out the back door or 50 miles away at a dark site. What's important is that it works for you. In most cases, a location closer to your house works best. This almost certainly will involve some compromises: limiting visual magnitude, buildings and trees blocking some sections of sky, even direct light from security and streetlights.

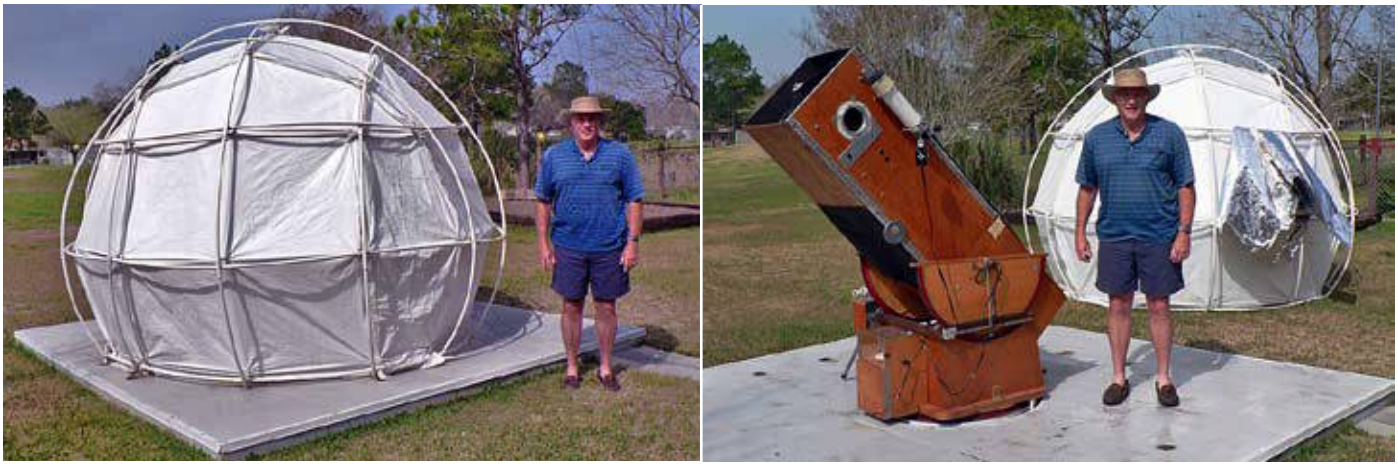
How will you use your building?

Next, will your observatory simply house a telescope, or does it need to accommodate people? If your main interest is the astrometry or photometry of asteroids, and you'll have a CCD camera connected to the telescope 100 percent of the time, you don't need a structure much larger than the telescope itself. If, however, you're like me — more of a social observer who enjoys having friends over — a larger observatory is a must.

Pick the size for your needs

Take three considerations into account as you mull over the size of your future observatory. The first involves the available space. How big can you build your structure? Size was the limiting factor for my observatory. With our fenced-in backyard plus an existing outdoor shop, I simply could not make the observatory any longer or wider.

The second consideration is the number of telescopes the observatory will house. Your plans may include more than one



Amateur astronomer Al Kelly built a pad on which he placed his 17.5-inch Dobsonian-mounted reflector. Kelly then used a dome he purchased to protect his telescope from the weather. The light-colored dome also kept the scope cool during sunny days. Al Kelly

This observatory, located in Nussbach, Austria, serves as astroimager Bernhard Hubl's primary setup. The telescope pictured is a 12-inch Newtonian reflector. Hubl uses a Keller Newton reducer on this scope to achieve a focal ratio of 3.8. Bernhard Hubl

permanent telescope, or perhaps one permanent pier with interior space for another scope on a portable mount. If so, account for that from the start.

The third issue is money. It's not the primary consideration because you'll have no idea how much, even in general terms, the observatory will cost without knowing its size or how many telescopes it will contain. And while larger observatories cost more, twice as large doesn't always mean twice as expensive.

Dome or roll-off?

You'll have a choice of placing a dome on top or using a roll-off roof design. A primary factor is aesthetics. Non-observers usually associate a traditional observatory building with a dome. However, a dome can clash with its surroundings.

Local ordinances may forbid domes. However, I know an observer who selected a dome because of existing tax laws. In his location, the area covered by a roll-off roof when it was open was subject to additional property taxes.

Domes are better at reducing stray light because only the slit is open to the sky. But roll-off roofs radiate trapped heat more quickly. Domes will protect you better on windy nights. Roll-offs allow a more impressive vista of the sky.

If you choose a dome …

Most amateur astronomers who select a domed roof purchase a ready-made dome from a manufacturer. (Visit www.Astronomy.com/toc to download "Choose the dome that's right for you," which appeared in the May 2008 issue of *Astronomy*.) Your option is whether to have the manufacturer install the dome or do it yourself. The choice depends on your construction skills and level of confidence with such a project.

Of course, you can't just order a dome and be done with it. First, you have to construct the building the dome will sit on, with the "mating ring" made to exact specifications.

Occasionally, amateurs have built their own domes. Certainly if you have the skill, you can build a form for a single "orange slice" panel, construct the required number, and then bolt the sections together to yield a dome. Just so you know: Getting the curvature right so that it assembles into a smooth dome is no easy task.

If you choose a roll-off roof …

For a roll-off, plan a gabled (triangular) roof, which prevents rain or much snow from accumulating. Also, you can purchase premade triangular roof trusses, although you may have to alter your design slightly if you can't find them in the right size.

Next, consider how you want the roof to roll, mechanically speaking. Many caster styles are available in plastic or metal. They roll in tracks or metal troughs. Be certain your casters have a large enough weight rating for your roof, plus snow.

For my observatory, I chose steel V-groove casters, which rode on an inverted steel L-bracket. I installed four casters on each side of the roof. This load capacity was more than I needed, but the roof rolled more smoothly on eight casters than on six. The only maintenance required was a quick lubrication every 3 months or so.

1) Brian Lula from Princeton, Massachusetts, begins construction of his Heaven's Glory Observatory II in New Mexico in July 2004 with concrete support placement. 2) One month later, he pours the concrete piers. 3) In October, he attaches the wooden decking. 4) Lula attaches the exterior and finishes the

Design your roof so it minimizes entrance by wind and rain. The roof should overhang horizontally at least a foot in each direction. Some amateurs also drop a panel down from near the roof's outside edge to minimize dust blowing inside.

Be sure the roof is secure when you close it. I used two steel turnbuckles. In the southwestern desert, spring winds are often strong. The observatory's roof has had no problems surviving wind speeds of 60 mph (96 km/h). Other observatory builders I know employ steel hasps, usually one in each corner.

Some amateurs, purely for aesthetic reasons, design their roofs so they overhang the tracks' ends by a small amount. This shortens the length of the outriggers — the wooden rails to which you attach the angle iron (on which the casters ride). Other builders make the outriggers longer than they need to be so the roof slides off beyond the building's edge. This minimizes the amount of sky the roof blocks in the direction it opens.

Install a high-quality floor

You have two options for flooring: wood or cement. A poured cement floor is virtually maintenance-free. Make certain you use a quality grade of cement. I wish I had. The people I hired to pour the cement floor used too much sand, and I had to patch numerous areas.

If you decide on wood, choose preservative-treated lumber. Elevate the floor to allow sufficient air circulation, which prevents mold and mildew. Having the structure off the ground is also beneficial because rodents will not nest in an unconfined, open space. Allow approximately ¼" of spacing between the top floor boards so that cold air does not pool in the observatory.

Wood flooring is more forgiving on your feet than cement, especially during a long January session when you plan to observe Mars near opposition. Adding a thick carpet remnant for extra padding will make your feet feel better.

The observatory's walls

How high you make the walls is a critical decision. If people will use your observatory, its walls must block any direct light while still allowing access to as much sky as possible. About 7 feet (2.1 meters) is a standard height. Large observatories may need higher walls to cut off direct lights.

Amateurs have built walls out of brick, concrete block, tile, siding, and plastic. I chose plastic. Thick walls retain heat. You can buy overcoatings that reflect sunlight, but my observatory was in the desert where coatings abrade rather quickly.

For the outside walls, I used an ultraviolet-resistant PVC paneling called PalRuf, which the manufacturer guarantees for 20 years. The panels are corrugated, approximately 3 millimeters thick, and come in 26" by 96" (0.66m by 2.4m) sections. You can cut the panel easily with utility scissors.

I covered the wall edges with a galvanized ridge cap, and I secured the panel with roofing screws, which self-sealed via attached neoprene washers. The panels greatly reduced solar heating, a major consideration in the desert.

The PalRuf I used for the walls is white, but that's a bad color for the interior of an observatory because of the possibility of stray light reflections. I painted the interior of the observatory flat black. When inside the observatory for an extended period of time, I gained more than half a magnitude to my limit because of the black walls.

I attached the panels to a wooden frame of 2x4s. You choose whether or not you apply a facing material to the interior walls. If you don't (my recommendation), you can use the braces for the upright 2x4s as shelving. The only reason to finish the interior walls is for appearance, but then it won't cool as quickly.

Your observatory's door will get plenty of use. Select a high-quality solid-core door with good hinges, a tough lock, and a good seal all around. Add a deadbolt for extra security.

Attached rooms

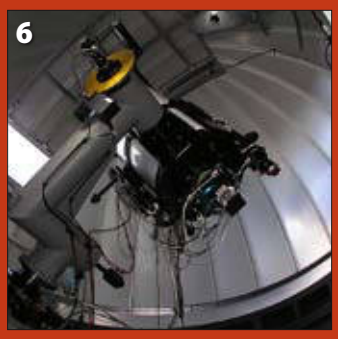
Some amateur astronomers who live in cold climates have attached a "warm room" to their observatories. You'll really appreciate this addition if the observatory is not close to home. For a backyard facility with a computerized telescope, this may be a better option than running control lines from the house.

If you build a warm room, you must insulate the wall between it and the observatory. Heat currents are the bane of seeing, and even the roof of the warm room will give off enough heat when the room is in use to degrade any images in the part of the sky above it.

Interior considerations

The most important interior consideration is power. Most amateurs install an electrical sub-panel in the observatory. Allow for at least two 15-amp circuits. If you're building a warm room, add at least two additional circuits, and one of them must provide enough amperage to operate the heater you plan to install.

Lighting is the second interior consideration. Dimmable red lights are mandatory. Dimmable white lights are optional.



roof. 5) The dome's arrival and installation is a big step toward the facility's completion. 6) The telescope begins operation January 2006. 7) January also sees the completion of the control room and "live-in" quarters. 8) The finished observatory is attractive, functional, sturdy, and secure. Brian Lula

A roll-off roof design (top) works best for imager Chris Schur. Inside, the observatory houses an 8-inch Schmidt camera. Chris Schur

Next is ventilation. If you seal your observatory too tightly, you'll have heat retention problems no matter how well your roof and walls reflect sunlight. Some amateurs use passive venting; others use quiet, low-flow fans.

If you have the space, do yourself a big favor and build in some storage shelves or cabinets. If space is limited, consider a rolling tool cabinet. You'll be surprised by how much one can hold. If you choose a roll-off roof, how will you use the room's corner spaces? Be sure to leave space around the telescope(s) for observing chairs or ladders. A great way to acquire extra storage without taking up floor space is to use pegboard panels. It's amazing how many items can hang on hooks. And don't forget a clock. Pick one with large — preferably red — numerals.

Putting in the pier

The column that supports the telescope and protrudes from the footing is the pier. Most amateurs install a pier for their main telescope. If you are planning this, a footing — a reinforced concrete block set into the ground — is essential. The scope's mount attaches to the pier via bolts preset into the concrete. Alternatively, you can attach a thick steel plate to the bolts in the concrete and then attach the mount to the plate.

A footing should be twice the width of the pier and as thick as the pier in depth. Many builders go beyond this rule. Make the footing square. The stiffness of a square section is 1.7 times more rigid than a circular section of the same length. Check your local building code for proper footing depth.

Many builders who choose a round concrete pier use a thick-walled tube sold under the name Sonotube. The tube comes in widths of 8 to 56 inches (20 to 142 centimeters) and lengths up to 18 feet (5.5m). If you install a Sonotube pier above a footing, "pin" the pier to the footing with rebar that protrudes 12 inches (30cm) or so out of the footing.

Whether the observatory has a cement or wood floor, you must isolate it from the pier. This is especially important for an observer planning to image. A 1-inch (2.5cm) gap is enough space, but this isn't a hard rule. Do this right, and you'll be able to dance in your observatory without affecting the images.

Please note that a lot of builders hand-mix the concrete for their piers to save money. Unfortunately, you can never hand-mix bagged concrete to the strength of quality-controlled ready-mixed concrete from a batch plant.

The final tally

Finally, after considering all of the above, the ultimate question is whether you do it yourself or have the observatory built for you. The observatory I built, which measured 9' by 10' (2.7m by 3m) when closed, cost me only $1,175. That total includes having a company pour a cement pad.

Whichever path you choose, use high-quality materials. Don't rush. Have an overall plan. Start with a blueprint or a detailed diagram. Document the building process, and, when you finish your observatory, send me some pictures. I might feature several projects on web blogs or in future articles.

DayStar's Quantum filter reveals the Sun

With solar activity on the rise, now may be the time to invest in a Hydrogen-alpha filter.

by Mike D. Reynolds

If you're an amateur astronomer whose "day" begins at sunset, I have a revelation for you: Sun-watching has become a popular pursuit. If you're not already on the solar bandwagon, you could be missing half your potential observing time.

Studying the Sun also is an essential part of professional research as scientists attempt to understand how stars work. Whether amateur or professional, however, the best way to observe the Sun is to eliminate all but a narrow part, or wavelength, of the light it emits.

DayStar Filters of Warrensburg, Missouri is one of the pioneers in high-quality commercial Hydrogen-alpha (Hα) filter systems for solar viewing. Since 1975, amateur and professional astronomers have used DayStar filters, and they have even orbited in spacecraft.

For this review, I tested the DayStar 0.5 Å Quantum SE filter. DayStar makes two types of Quantum filters. The SE series fills the needs of most amateur astronomers and some in education. The PE series is designed for professional research applications.

The DayStar Quantum Hα filter requires a heated etalon, an optical filter that has a narrow bandwidth at the required wavelength. DayStar produces Hα filter systems in 0.3 angström (Å) to 0.8 Å bandwidths in 0.1 Å increments.

DayStar Filters' 0.5-angström Quantum SE Hydrogen-alpha filter will allow you to observe and photograph the Sun's chromosphere, prominences, and flares. *Astronomy*: James Forbes

An energy-rejection filter attaches to the front of a telescope. It blocks ultraviolet, infrared, and most visible light, reducing the heat on the Hydrogen-alpha filter. *Astronomy*: James Forbes

The Hydrogen-alpha wavelength

The most popular narrowband solar-observation wavelength is Hydrogen-alpha (Hα). The Hα emission line occurs when a hydrogen atom's electron makes a transition from a higher energy level (the third) to a lower one (the second).

The atom emits this energy at 6562.8 angströms (Å). This allows astronomers to view solar features like prominences and the chromosphere, which glow at this wavelength but are not normally visible. Visually, our eyes detect light in a range from 4000 Å (violet) to 7000 Å (deep red). But to view the Sun in Hα light takes a special filter.

A measure of light wavelength, 1 angström equals one ten-billionth of a meter. Narrower bandwidth filters — say, a 0.3 Å versus a 0.5 Å filter — reduce off-band transmittance and increase the contrast.

DayStar incorporates a green light that indicates when the filter is on-band. Easy-to-use redshift and blueshift buttons can tune the wavelength up or down precisely. A serial port allows computer control capability and filter readout display. In addition to a full Hα filter line, DayStar offers other specific wavelength systems, such as Calcium H (3969 Å), Calcium K (3933.7 Å), and Sodium D (5895.9 Å) filters.

***Astronomy* contributing editor** *Mike D. Reynolds is the Dean of Liberal Arts & Sciences at Florida Community College — Kent Campus.*

Specifications

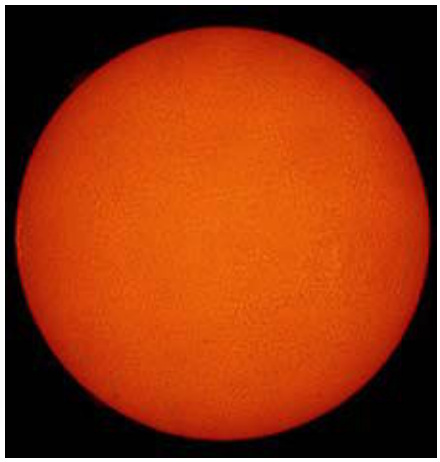
DayStar Quantum SE Filter

Type: Hydrogen-alpha
Bandpass: 0.5 angström
Focuser: 1¼" rack-and-pinion
Usable f/ratio: f/30 and higher
Display: Liquid crystal (LCD)
Accuracy: 0.1 angström
Included: Power supply

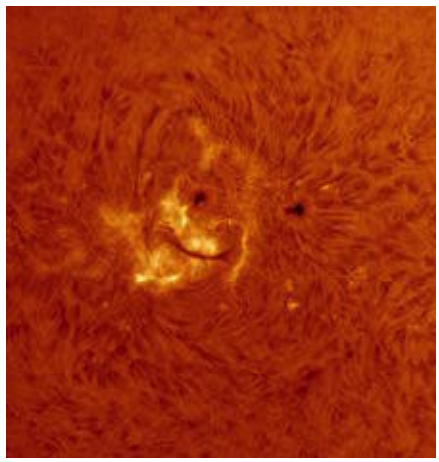
For the review, I also used a DayStar full-aperture energy rejection filter, or ERF. The ERF mounts on the front end of the telescope. It reduces the heat load on the filter assembly by absorbing or reflecting ultraviolet, infrared, and most visible light. Reducing the heat load lets the Quantum filter function more efficiently. It also gives it a longer usable life. Reducing the amount of energy that strikes the filter helps protect the system's blocker and trimmer elements, which tend to degrade with use.

I mounted the filter on a 6-inch f/8 Celestron CR 150 HD refractor and a 7-inch Meade f/15 Maksutov telescope. I had to use a Barlow lens with both telescopes to achieve an effective focal ratio around f/30. The system requires such a focal ratio because the light entering the filter must be as close to parallel as possible. Faster f/ratios (below f/30) allow light to strike the filter at steeper angles, providing a sub-par performance.

The Quantum SE filter has a digital wavelength readout. The red and blue buttons tune the wavelength up and down precisely. *Astronomy:* James Forbes



This full-disk solar image shows a few prominences, but, because we're near solar minimum, not a great amount of activity. The photographer used a DayStar 0.45 Å Hydrogen-alpha filter to acquire this image. Fred Bruenjes



A solar flare appears white through an Hα filter. The small, dark areas above and to the right of the flare are sunspots. The photographer used a DayStar 0.45 Å Hydrogen-alpha filter to acquire this image. Fred Bruenjes

You can increase your optical system's focal ratio in two ways: either with a Barlow lens or by employing an aperture mask (which reduces the aperture size, thus increasing the focal ratio). I used a Tele Vue Powermate telecentric system. For the Celestron telescope, I used a 4x Powermate, giving the system an effective focal length of f/32. For the Meade scope, the 2x Powermate provided an effective focal length of f/30.

The complete ERF-telescope-Powermate-Quantum SE filter system was easy to set up because the directions supplied with the filter are foolproof. The Quantum SE filter operates on 12 volts of DC power.

Once the Quantum SE filter powered up, it took about 8 minutes to warm the optics to the proper temperature. As the filter heated up, it reached 6562.8 Å and stopped. The indicator light turned from yellow to green. DayStar's digital readout clearly showed the current wavelength — a terrific feature!

The readout has an accuracy of 0.1 Å. It can also display error codes, such as voltage variations or internal malfunctions, none of which I experienced during testing.

Through the Maksutov, I quickly determined what proper focus should look like and how to tune the filter using the red and blue buttons. Those buttons change the filter's wavelength by small amounts. This allows the observer to adjust the filter's temperature for the best image. Some Hα filter systems tilt the etalon to make this change.

Solar views through the Quantum SE Hα filter were superb. With a little practice, I'm sure I could take great images. Based on my tests, a high-quality, short-focal-length refractor will produce excellent solar images.

A longer-focal-length optical tube assembly would make achieving the f/30 recommended effective focal ratio easier, but the correct Powermate and/or an aperture mask can help you do that. With DayStar's Quantum SE Hα filter, even a quiet Sun — like we are now experiencing — will look spectacular.

Contact information

DayStar Filters
149 Northwest OO Highway
Warrensburg, Missouri 64093
[t] 660.747.2100
[w] www.daystarfilters.com

Observing Basics

by Glenn Chaple

Feast on Saturn

Use 2009's edge-on appearance to observe the planet's other features and its moons.

Galileo was baffled. In July 1610, having already discovered moons in orbit around Jupiter, the Italian astronomer directed his telescope toward the planet Saturn. He probably wasn't surprised to see two new "stars" bracketing Saturn's disk. After all, four accompanied Jupiter! But that quartet performed a night-to-night dance around their master, while Saturn's duo remained fixed.

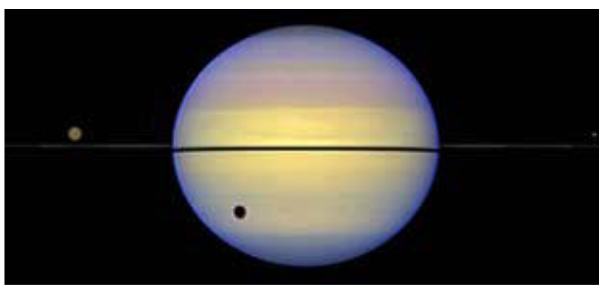
The mystery deepened when Galileo revisited Saturn 2 years later. The stars were nowhere to be seen! "Has Saturn swallowed his children?" he wrote. Galileo began to doubt his earlier observations, acknowledging that the optics of his crudely fashioned telescope might be to blame. Undaunted, he predicted the companion stars would return within a few years. They did, and Galileo saw them not as stars, but as "ears" or "jug handles" affixed to Saturn.

Galileo never did solve the riddle of Saturn's enigmatic companions. Nearly a half century passed before improvements in telescope design enabled Dutch astronomer Christiaan Huygens (1629–1695) to recognize their true nature. What Galileo perceived as "jug handles" was actually a thin, flat ring surrounding Saturn.

Galileo was a good observer who used bad equipment. Today, anyone who wants a close-up view of Saturn can purchase a high-quality telescope for the job. Galileo didn't have that luxury. The telescope only recently had been invented, so none was available commercially. Galileo had to construct his own, even hand-grinding the lenses. His home-built refractors were primitive by today's standards. They produced spurious images and inadequately low magnifications.

So with better equipment, Huygens made the discovery Galileo couldn't. Not only did he ascertain the nature of Saturn's rings, but he also explained why Saturn "swallowed his children." Saturn orbits the Sun once every 29.5 years. Twice during that cycle, Earth and Saturn are positioned so that the rings appear edge-on to our line of sight — an event called a "ring-plane crossing." Saturn's rings are so thin (on the order of a few dozen yards), they seem to vanish from sight. A ring-plane crossing was in progress when Galileo viewed Saturn in 1612. Saturn's children hadn't been swallowed. They were hiding!

This year we'll again see Saturn's rings edge-on. The actual date of the 2009 ring-plane crossing is September 4, when Saturn will be just 11° east of the Sun, lost in the early evening twilight. Right now, the rings appear quite thin — mere extensions of Saturn's disk.



Saturn's rings turn edge-on this year, allowing observers to study the planet's disk and system of moons. Erich Karkoschka (LPI)/NASA

We may bemoan the loss of Saturn's beautiful rings, but their near-absence will reduce the planet's overall glare, making it easier to go moon-hunting. The brightest is 8th-magnitude Titan, which Huygens discovered in 1655. A small backyard scope can capture this moon — it circles Saturn once every 16 days. The tiny speck we see when we peer into the eyepiece belies Titan's true nature. This appropriately named moon is 50 percent bigger than our Moon and second in size in the solar system only to Jupiter's Ganymede.

Besides Titan, look for Rhea (magnitude 9.5), Tethys (magnitude 10.0), and Dione (magnitude 10.2). You might also glimpse Iapetus when it's on Saturn's west side, shining at 10th magnitude. When it's east of Saturn, this moon is 5 times fainter. The fade-away happens because one side of Iapetus is bright and highly reflective, and the other is dark. You can glimpse all of these moons on a clear, dark night through a 6-inch telescope. Owners of 4-inch scopes with steady air overhead might try for them as well. (See page 42 in "The Sky this Month" for more information on the paths of Saturn's moons in March.)

After toying with Saturn's moons, take a look at the planet. We don't often see Saturn's disk this well because the rings are usually in the way. Its flattened appearance isn't an illusion. Saturn's rapid rotation (a saturnian "day" is a little more than 10 Earth hours long) and gaseous composition combine to produce a noticeable equatorial bulge. Look carefully (100x or more will work), and you might see belts in subtle shades of yellow and light brown running parallel to Saturn's equator. A hazy shroud of ammonia ice crystals envelops the planet, making its low-level cloud belts much subtler in appearance than Jupiter's.

Don't be disappointed by the absence of Saturn's rings this year. They'll begin to open up in 2010 and will again evoke gasps of awe and wonder from telescope users until the next ring-plane crossing in 2025. For now, as Saturn "swallows his children," we can feast on Saturn!

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: a buzz around the Beehive.

Binocular Universe

by Phil Harrington

Messier madness

Spend the month attempting the Messier Marathon with binoculars.

On your mark! Get set! Go! It's time for March Messier Marathon madness.

Each year right around the vernal equinox, the heavens align such that — depending on your location — all of the Messier objects are visible sometime between sunset and sunrise. And this year is just about perfect because New Moon is Thursday, March 26. That means we have two good weekends, March 21/22 and 28/29.

Some doubters might question using binoculars for the marathon. But they're wrong; most Messier objects can be seen through surprisingly small binoculars. So, this month, I'd like to tempt each of you to try a Messier "bino-thon." Of course, the complete bino-thon runs the entire night, but for now, let's stick with a few in the evening sky.

Among the most difficult Messier objects to find during March are the six that set shortly after the Sun. Two, M74 in Pisces and M77 in Cetus, are beyond the grasp of most binoculars even when they are high in the sky, so we'll pass on them. Of the other four, the Andromeda Galaxy (M31) is an easy catch on dark autumn and winter nights. Now, however, Andromeda hovers low in the northwest, and you'll need a clear view to spot it. But if you succeed, don't forget about its two galactic companions, M32 and NGC 205 (often called M110). I saw all three through 16x70 binoculars during my cloud-shortened 2008 bino-thon, but caught only M31 through my 10x50s.

If you find M31, then M33 in Triangulum may also be possible. I nabbed it through my 16x70 binoculars last year, but not with the 10x50s.

The last critical evening target is globular cluster M79 in Lepus. To locate it, extend a line from Alpha (α), south through Beta (β) Leporis, to a lone 5th-magnitude star. M79 is just ½° to that star's east. Don't be discouraged if you miss, however. It's tough.

M46 and M47 are two open clusters in the constellation Puppis. M46 contains more than 150 bright stars and is about 300 million years old. Its younger neighbor M47 is a smaller bright cluster of some 50 stars. Luke Dodd

Many early evening Messier objects, such as the Orion Nebula (M42) and the Pleiades star cluster (M45), are easy to spot, but others will test your skills. One that comes to mind is number 1 on the list, M1, the famous Crab Nebula in Taurus. I can still remember the cold January night back in high school when I first spotted the Crab through my old 7x35 binoculars. I was in my backyard, lying in a snow bank and scanning the winter stars. I thought it might be fun to see how many Messier objects I could see and figured it was appropriate to start at the beginning. I didn't expect it, but sure enough, M1 was there! You can see it, too, if you look just to the northwest of Zeta (ζ) Tauri.

Finally, three striking Messier open clusters lie in the vast starless void east of Sirius (Alpha Canis Majoris). They all are bright, but finding them can be tough because of the sparse surroundings.

Head east of Sirius to the star Gamma (γ) Canis Majoris. Continue eastward, past a triangle of faint stars, to a second slender triangle. That second triangle frames M46 and M47. The western cluster, M47, looks like a hazy blotch peppered with several pinpoints of light through binoculars. The cluster itself is quite pretty, especially when combined with its starry surroundings.

M46 is just east of M47. Unlike its neighbor, which has several stars within the grasp of most binoculars, M46 is a rich congregation of faint stars. Most binoculars show only a hazy glow, maybe with just a few faint specks within.

Once you find M46 and M47, slide southward a little more than a field's width to M93. Look for it just above a crooked rectangle of four stars, including Xi (ξ) Puppis. I can see about half a dozen stars mixed throughout a dim glow that, to my eyes, looks triangular.

OK, the race is on! If you want to continue this hunt in the sky, head over to Astronomy.com this month for a checklist showing my preferred finding sequence. And if you enjoy looking for Messier objects through your binoculars at a more leisurely pace, check out the Astronomical League's Binocular Messier Observing Club. You'll find information on the Web at Astroleague.org.

Last year, George Robinson of Auburn, California, caught 94 Messier objects through his 15x63 binoculars during the annual All-Arizona Messier Marathon. Good job, George. I'd love to hear how the rest of you do with your own bino-thon this year. E-mail me your results at phil@philharrington.net. And until next month, remember, two eyes are better than one.

Find Harrington's Messier bino-thon sequence at www.Astronomy.com/toc.

New Products

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Massa, Italy

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Starizona
Tucson, Arizona

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[w] www.telescope.com

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Temecula, California

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Price: $13,995
[t] 800.570.2600
[w] www.chronosmount.com

Rotating pier plate for AP900

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[w] www.jmitelescopes.com

30mm 82° eyepiece

Explore Scientific
Laguna Hills, California

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Torrance, California

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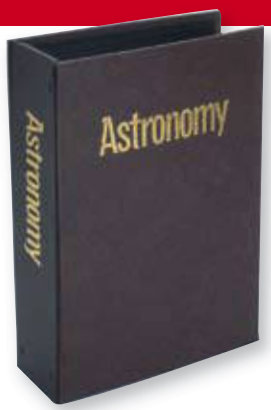

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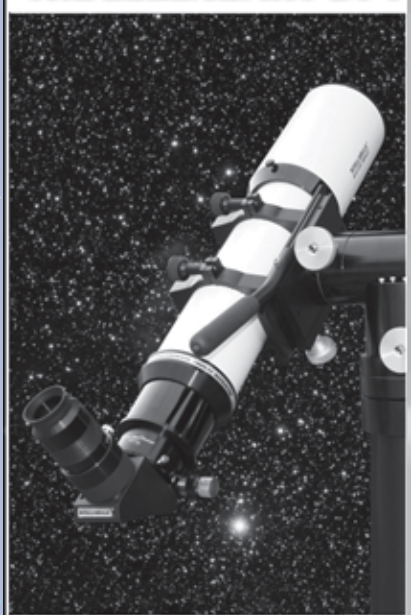
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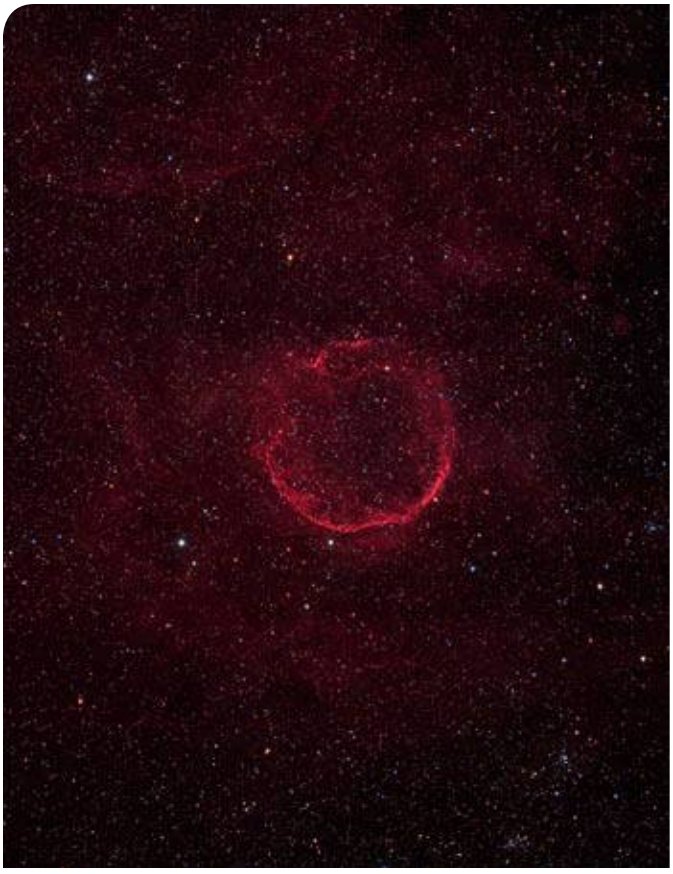
IC 2574 (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, Santa Barbara Instrument Group ST-10 CCD camera, LRGB image with exposures of 6.5, 1.25, 1.6, and 2 hours, respectively) • Image by Martin Winder; processed by Dietmar Hager, St. Johann am Wimburg, Austria

The Medusa Nebula (Sharpless 2–274), also known as Abell 21, is a planetary nebula in Gemini the Twins. (5.6-inch Telescope Engineering Company TEC140 apochromatic refractor at f/7, SBIG ST-2000XM CCD camera, LRGB image with exposures of 40, 110, 80, and 110 minutes, respectively) • Ruben Kier, Orange, Connecticut

What's in a name?

Coddington's Nebula (IC 2574), above, is not a nebula at all. Rather, it is a magnitude 10.2 barred spiral galaxy that lies 3° east of the better-known Bode's Galaxy (M81). IC 2574 also is a deep-sky object few amateur astronomers have imaged. It spans 13.2' by 5.4'.

British astronomer Edward Foster Coddington (1870–1950) discovered this galaxy, which now carries his name. IC 2574 contains many active star-forming regions, seen in this image as reddish clumps throughout the galaxy's spiral arms.



< Supernova remnant CTB1 in Cassiopeia floats in a colorful star field. CTB1's expanding border appears discontinuous, with a "break" at approximately 11 o'clock. (4-inch Takahashi FSQ-106 at f/5, SBIG STL-11000 CCD camera, HαRGB image with exposures of 360, 60, 60, and 90 minutes, respectively) • Steve Cannistra, Needham, Massachusetts

v Open cluster M48 (NGC 2548) floats in Hydra 14° southeast of Procyon (Alpha [α] Canis Minoris). The cluster shines at magnitude 5.8. (6.4-inch Astrophysics AP160 StarFire EDF apochromatic refractor at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with 30-minute exposures through each filter) • Anthony Ayiomamitis, Athens, Greece

^ The Jewel Box Cluster (NGC 4755) in the southern constellation Crux is the sky's 12th brightest open cluster. It shines at magnitude 4.2. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee U16M CCD camera, RGB image with five 1-minute exposures through each filter) • Don Goldman, Orangevale, California

> The Blackeye Galaxy (M64) shines at magnitude 8.5 in Coma Berenices. The dark region is dust, which obscures stars behind it. (12-inch Meade LX200R telescope and an SBIG ST-10XME CCD camera for 285 minutes of luminance; TEC140 refractor and an SBIG ST-2000XM CCD camera for color; the RGB image had exposures of 90, 60, and 80 minutes, respectively) • Ruben Kier, Orange, California

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The zodiacal band cuts diagonally (bottom left through upper center) through the southern heavens in this all-sky view. The band is reflective dust in the solar system's plane. The brighter patch above center is the Gegenschein, or counterglow. It lies directly opposite the Sun as we see it from Earth and glows more strongly than the rest of the zodiacal band. You'll find the Large and Small Magellanic Clouds at the image's bottom right. (Canon XTi digital SLR, Sigma 8mm lens at f/3.5, 10-minute exposure, ISO 800, taken in Winton, Australia) • **Chris Schur, Payson, Arizona**

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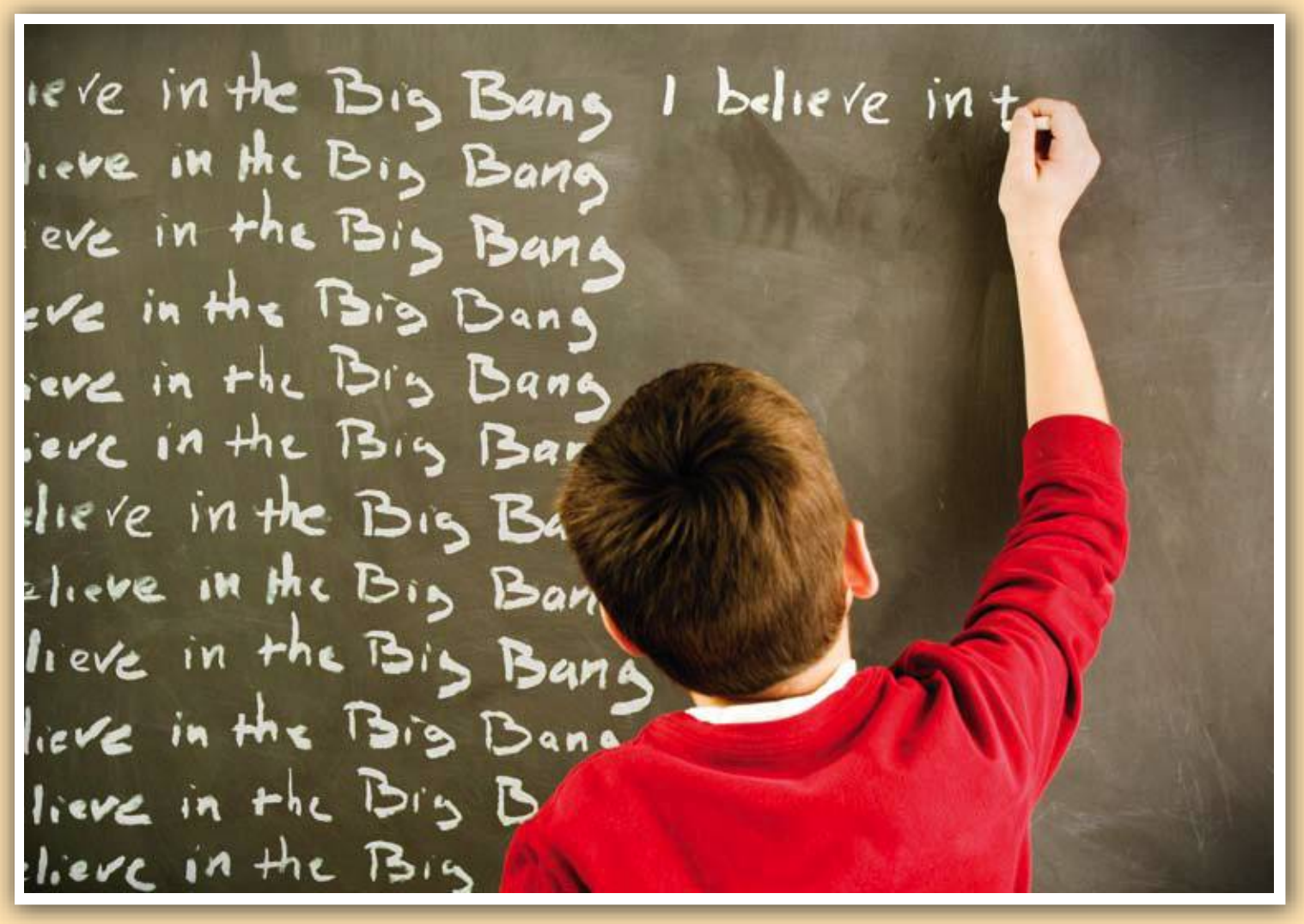

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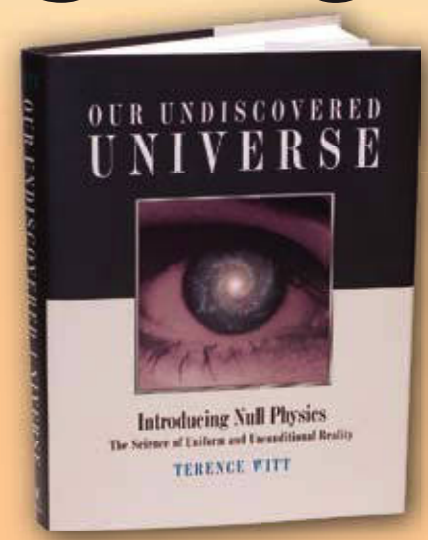

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